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A Planned Engineered Agriculture[1]

By F. W. Duffee[2]

IT SEEMS TO ME that the first great era in American agriculture came to an end sometime about the year 1921. It is true that this era, covering the time from the discovery of this country up to 1921, can be divided into many smaller periods or phases. However, throughout all this period of time from 1492 to 1921 there were, it seems to me, certain factors in operation that contributed greatly toward making agriculture what it has been, things that have made the American farmer the most prosperous farmer of the world and of all time; and that some of these important things have changed. Some of the factors that have contributed so much to prosperity in the past are gone, and gone for all future time and generations.

What are these things that have slipped away from us never to return? Principally cheap land and virgin soil.

Why do I say this era came to a close about 1921? I mean that, generally, land values showed an increase up until 1921. Probably these land values had reached about a normal level around 1914, but the World War gave them an additional impetus which collapsed about 1921, and land values have been receding ever since. I do not believe any of us living now will ever see such high prices again, unless we have a world-wide calamity or war.

Someone has aptly described this period of increasing land values as being "a time when you could start in business with nothing, lose money in the business every year, and finally retire on your income." The explanation is simple—rising land values. Many of the older men now living have retired on the income derived from money acquired due to rising farm land values, but the young men of today must look to some different source for a retirement fund.

The other lost element that contributed much to a prosperous farming era, was the virgin soil, rich with the accumulated fertility of countless centuries. We have to a large extent milked the soil of this accumulated fertility of ages, and, what is worse, we have so farmed that erosion has completely robbed us of our top soil in many places and is still robbing us of millions of acres. Obviously, we have yet tremendous resources of natural fertility. The important point I wish to emphasize is that the bountiful fertility of the virgin soil is gone, and we are now faced quite generally with the problem of carefully conserving fertility from now on. Throughout rapidly widening areas, artificial fertilization is becoming necessary.

It seems to me that we cannot expect the ratio of farm to urban price levels of 1909-1914 to return for many years. Even if they do, the farmer will be living on a 1914 basis, except in so far as he has increased the size or efficiency of his business. If a farm of 160 a supplied the living requirements of 1914, it will take a larger farm or a more efficiently operated farm to provide the living comforts of 1932, assuming 1914 price ratios.

This means that if we are to restore agriculture to its former place, we will have to do it through profits made in the business itself. When this depression is over, and there is every reason to believe that it will end, we must look to different and better methods of farming, out of which to make farm profits. Science and business management will have to be applied as never before, if farm buildings are to be maintained and replaced as needed; if the farmer is to enjoy a modern home; if he is going to maintain an automobile, and all the things that make a modern scale of living.

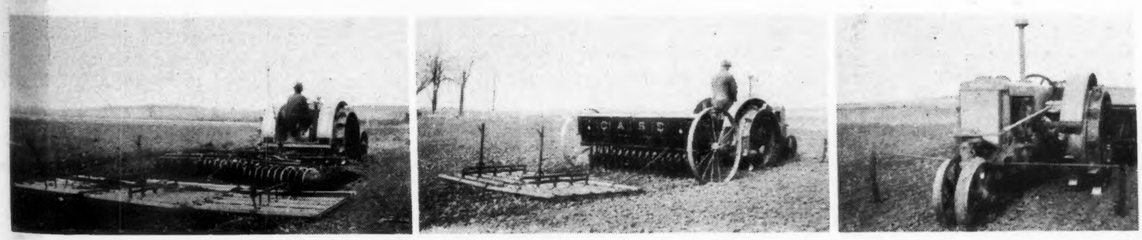
The agricultural engineer is largely concerned with the problem of production, although he can and should make an important contribution especially to land utilization problems.

The last thirty-two months have demonstrated that in spite of a phenomenal development not only in agricultural equipment lines, but in every technical phase of human endeavor, all is not right with the world. There is a general awakening to the need of planning our progress for the future. Let me call to your attention some examples of what I mean.

Two of the most outstanding developments of the last 20 yr in the agricultural equipment field have been the tractor and the combine. By means of these machines, the output per worker has been tremendously increased. The terms "man-hours per acre" and "man-hours per bushel" have come to be pet expressions of the agricultural engineer. The implement companies, aided to some extent by the agricultural experiment stations, have developed

[1]Paper presented at the 26th annual meeting of the American Society of Agricultural Engineers, at Ohio State University, Columbus, June 1932.

[2]Professor of agricultural engineering, University of Wisconsin. Mem. A.S.A.E.



(Left) Preparing the seedbed for spring seeding of small grain after fall plowing. Once over gives a good seedbed in this soil. Note that a 15-ft harrow is used behind the 10-ft tandem disk. This arrangement levels off the furrow usually left by the outside of the tandem disk. (Middle) Seeding grain, fertilizer and grass seed on the same farm as shown at the left. Note the guide on the front of the tractor, at the extreme right of the picture; this very materially improves the accuracy of driving. (Right) A simple, homemade driving guide to facilitate accuracy of driving

what today seem to be wonderfully compact, efficient, durable machines of wide adaptability.

Agricultural engineers in the agricultural experiment stations have studied the performance and efficiency of these and other machines, and have reported profusely upon them, usually in terms of more or less abstract units such as "pounds per horsepower-hour" or "man-hours per bushel or per acre." But the complicated management problem involved in the adoption of this equipment has been almost wholly neglected from a research point of view.

We have on the farms of the United States nearly 1,000,000 tractors and 70,000 combines. I presume these machines would represent a first-cost investment of approximately $1,000,000,000 for the tractors and $105,000,000 for the combines. How much money have we spent in studying the reorganization of our farms so as to properly utilize this as well as other equipment. It seems to me we have had, not too much research along technical lines, but too little research along the economic lines referred to above. I wish to quote from an address by the Hon Victor Christgau of Minnesota in the House of Representatives on June 30, 1930; the following comments relative to a bill which he was introducing:

> "The measure provides a new economic research setup, cooperative between the United States Department of Agriculture and the state agricultural colleges and experiment stations, with sufficient continuous financial support as to allow coordinated regional production, economic and farm management investigations to be carried on upon the basis of the knowledge so obtained. Programs of farm readjustment and farm reorganization can be formulated which will permit the farmers to take advantage of changed economic conditions and changes in technique. In some cases it will make possible the systematic substitution of other enterprises for surplus-producing enterprises, especially where certain farm enterprises are now carried on in high-cost production regions.
>
> "As yet the public has given little attention to this feature of the agricultural problem of the United States. This condition is due partly to the lack of available funds to research institutions and the historical emphasis on production rather than on economics and farm management. Of the 2,500 agricultural research workers in the state agricultural experiment stations, it is doubtful if over 2 per cent are engaged in research work dealing with regional competition and advantage and the economics of agricultural adjustment and farm management. Of the total appropriations for the United States Department of Agriculture only approximately $200,000 are used for such purposes. Scarcely any attention is given to the matter by the 5,000 county agricultural extension agents scattered throughout the United States. This, undoubtedly, is due to the fact that they have no organized, systematic material of this nature upon which to base extension work and extension programs."

Economists tell us that many farmers own tractors with a resulting financial loss to the business, that many farms are supplied with more machinery than seems warranted. We must admit that these things are frequently true, not because the tractor is wrong, not because the use of machinery is wrong, but probably in these cases, because the farmer is trying to adapt mechanical power to horse-farming methods, or because he bought machines that were not practical and coordinated to his scale or type of farming.

The foregoing observations represent the philosophy back of a project which we have under way on the efficient utilization of labor, power, and machinery on Wisconsin farms. Its object is to determine what machines and what sizes of these machines are best adapted to farms of various sizes; what are the most economical arrangements, sizes, and types of power units; and the effect that use of different sizes and types of machinery and power units has upon the utilization of labor on farms of different sizes. Are certain sizes of farms apt to be more efficient from the standpoint of the use of labor and equipment than other sizes, that is, as between sizes of, say, 75, 100, and 125 a, and between sizes of 100 a, more or less, as compared to 300 or 500 a?

Various experiment stations have studied the use of machinery in the production of corn, wheat, etc, and have shown how low we are able to get the cost per bushel for that particular crop, but how about all the rest of the crops on a diversified farm? How about all the rest of the operators' time throughout the year?

I wish to quote from a statement which I solicited from Mr. H. S. Johnson, president, Gisholt Machine Company, Madison, Wisconsin, which concern is one of the leaders in the design and manufacture of machine-tool equipment:

> "Concerning the talk we recently had about the necessity of efficient farm management and its analogy to industrial management, while I am not familiar with farm procedure, I am very sure that there are common problems in the two activities. For example, a newly designed machine, to reach its maximum effectiveness, must have behind it the cooperation of management, and the processes of production must be coordinated in such a manner that it may function in the highest degree for the purpose for which it was designed. Frequently, in order to utilize such a machine, it may be necessary to somewhat change the design of the piece, particularly where the machine is used for a major portion of the work to be accomplished on it. This is not at all an unusual procedure.
>
> "One of the most vital things necessary to get the maximum out of a newly created machine is to see that it is so positioned in a plant and the processes are so controlled and coordinated that this may be done.
>
> "Doubtless, in the final analysis of present day progress, control and methods in the modern plant and the working units of machinery are about equally responsible for efficient production."

In order that you may have a reasonably definite picture of Wisconsin's agriculture to serve as a background for a brief resume of our project the following general data are submitted: The average size of farm is 120.3 a; average crop area, approximately 60 a; average plow land, about 80 a. Major items of gross income in 1929[3] were as follows: Milk, 52.4 per cent; cattle and calves, 12.2 per cent; hogs, 11.1 per cent; all crops, 15.6 per cent. Tractors on farms number between 55,000 and 60,000. Farm implement and machinery value per farm is $936.

During the spring of 1930 A. J. Schwantes[4] came to the University of Wisconsin to complete work for his master's degree. A part of this work consisted of a complete survey and study of the use of power, machinery, and labor on 100 typical, representative dairy farms scattered throughout Wisconsin. This study serves as the background and the starting point for our research work in farm organization and planning with special reference to the use of equipment and its effect upon the farm income.

For the farms included the average size was 169 a; average crop land acreage was 94, or 55.4 per cent; plow land averaged 114 a, or 67.5 per cent; average field size was 11.1 a; and average number of fields per farm was 10.3.

Fields might be increased to an average of 28.7 a, in so far as natural barriers were concerned. This is an important point as it indicates to us the possibility of larger farms. There was an average of 17.6 cows per farm. There were 60 tractors on the 100 farms, and an average of 4.4 horses per farm. The tractors average 307 h per farm, with the belt work taking about one-third and field work two-thirds of this time. The labor required on the average farm with 94 a of crop land and keeping 17.6 cows, was 23.9 man-months, the approximate equivalent of 2 men per farm the year around, or 47.4 crop acres per man. Table I shows the distribution of labor throughout the year.

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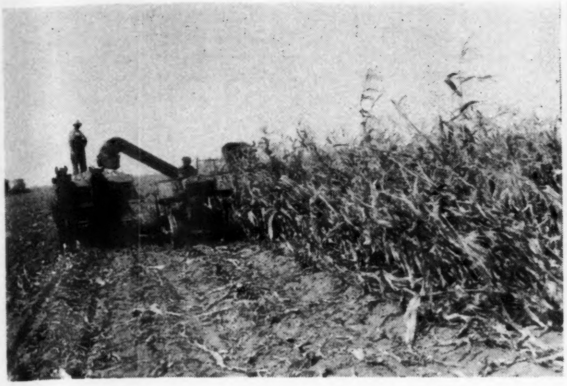
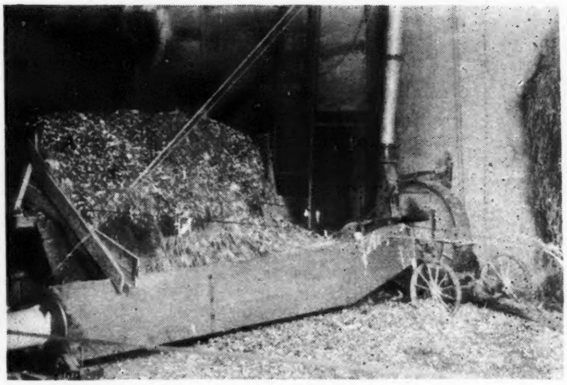
[3]Bulletin 120, "Wisconsin Dairy Statistics," published cooperatively by the U. S. Department of Agriculture and the Wisconsin Department of Agriculture and Markets.

[4]Associate professor of agricultural engineering, University of Minnesota. Mem A S A E.





(Left) Harvesting ensilage on Farm No. 1. The field ensilage harvester did an excellent job of gathering all the corn in spite of the fact that the corn was badly tangled and leaning. It required an average of about ten minutes to cut a load of about 1¾ ton. (Right) The cut ensilage, harvested as shown at the left, was unloaded by dragging the load off to the rear, somewhat similar to the principle of the manure spreader. A back-geared hay hoist driven by a 1½-hp engine was used. One man could unload about 1¾ tons in about 5 min actual unloading time, or in about 8 min, including the time required to get ready to unload and to get the wagon ready to go to the field after unloading

Table I. Man Labor Used on Livestock, Crops, and Miscellaneous Work[5]

County	Number of farms covered by records	Crop acres per farm	Milking cows per farm	Hours of man labor required yearly per farm for: Livestock production	Crop production	Miscellaneous work	Total
Barron	22	66	13	3,644	1,301	777	5,722
Fond du lac	19	92	18	3,921	1,928	1,008	6,857
Walworth	24	83	18	3,541	1,550	460	5,551
Average 3 counties		81	17	3,700	1,615	733	6,048

This table, covering the time from 1922 to 1929, inclusive, comprising 162 separate farm records and covering 1 to 3 years on each farm, was prepared by the agricultural economics department of the University of Wisconsin. The distribution of labor may be summarized as follows: Care of livestock, 61 per cent; production of crops, 27 per cent; and miscellaneous work, 12 per cent. We must bear in mind then that only about one-fourth of the total labor used on the average Wisconsin dairy farm is used for field crop production.

THE PROJECT

Two farm cooperators were secured for the "large farm" part of the study, as follows: No 1, having a total of 440 a with about 330 a in crops, and No 2, having 290 a with about 236 a in crops. A complete survey of the land was made and maps prepared, and an inventory of the farm was taken by the agricultural economists, who are cooperating wholeheartedly with us. The regular account books used by the farm management specialists were installed, and a complete financial record is being kept. Special work-record books were prepared for keeping a complete and detailed record of every minute of time spent on the farm, for every activity. This includes chores, repairing fences and buildings, time going to and coming from fields, time caring for, greasing and adjusting machinery, as well as the time spent at useful, directly productive work.

The then present machinery and power equipment was carefully analyzed as to its adaptability to the particular farm, with the result that some machinery was discarded and approximately $3,000 worth of additional new machinery was placed on Farm No 1 and $5,500 worth of machinery on Farm No 2. The resulting machine equipment represented what we considered to be the correct assortment of sizes and types, including the correct balance of mechanical and animal power to operate the farms most effectively from an "overall profit" point of view.

[5]From University of Wisconsin Bulletin No. 421, page 17.

Table II, taken from Schwantes' study clearly shows the comparison between these farms and the average of the 100 farms surveyed, as regards the investment in machinery. It shows that the investment in machinery per crop acre has been decreased from an average of $10.59 on the 100 farms to an average of $6.03 for the two experimental farms. Power investment was reduced similarly from $7.36 to $5.95 per acre and crop acres per man were increased from 47.4 to 94.3, an increase of almost 100 per cent.

Table II. Labor, Power and Machinery in Relation to Crop Acres on Experimental Farms

Farm number	Size (acres)	Number crop acres	Crop acres per drawbar horsepower	Value of power per crop acre	Value of machinery per crop acre	Value of power and machinery per crop acre	Crop acres per man
1	440	330	14.50	4.70	4.68	9.38	110.0
2	290	236	11.24	7.20	7.38	14.58	78.7
Average 2 farms		283	12.87	5.95	6.03	11.98	94.3
Average 100 farms		94	10.50	7.36	10.59	17.95	47.4

On No 1 farm 50 cows are milked, producing Grade A milk, with the labor of three men in the field and two in the dairy barn regularly. The crop acreage per man in the case of this farm is based on the field men only, which is not quite proper for direct comparisons, but it is the concensus of all who have contacted the project that three men could do all the ordinary work on this farm including the care of the herd, providing the regular grade of milk was produced. In fact the work of producing Grade A milk is being done this year on 350 a by about 3½ men.

On Farm No 2 of 236 crop acres, three men do the regular work, including milking 20 to 25 cows. We feel sure that this herd can be increased to 40 or 50 cows, and this expansion is going ahead just as fast as possible, in view of barn remodeling which is necessary, and also with the normal herd increase. It is the belief of the operators of this farm that they can milk 40 to 50 cows, and operate 275 to 325 a of crop land. Slightly over 300 rods of fence have been eliminated and some 350 rods reset so as to square and improve the shape of fields. There were 14

fields, outside of small pasture paddocks, with an average size in 1930 of about 18 a. Now there are 12 fields much more regular in shape, and the number will be reduced to probably about 10 fields as rapidly as the rotation will permit.

Unfortunately we cannot submit much in the way of definite data relative to field operations, or financial programs at this time. Suffice it to say that both operators seem to be convinced that they are in a stronger position financially at the present time than they would have been under the original system. However, it would be well to mention that Farm No 1 was increased from a total of 230 a to 440 a at the start of the project, and the man power increased by one man. Farm No 2 was increased from 250 a to 290 a with no increase in man power, except that one son is now on the farm full time, whereas during the first year of the project he was in high school about 9 months of the year.

The agricultural economists as well as the department of soils and agronomy of the University of Wisconsin, have rendered excellent cooperation and valuable service on this project. Farm No 1 produced 60 bu of corn to the acre on one 35-a field last year, and the year was extremely dry. This production is based on a weight of 75 lb per bushel at harvest time. The field results have been extremely satisfactory in every respect, and weed control is far above average.

Right here let me say that I stand four square in the defense of the agricultural economist, as regards his conservative attitude toward new machinery, or new machinery methods. It is unreasonable to expect him to recognize at a glance the merits of a machine, or the mechanical improvements in a tractor. His job is to accurately measure the results of that machine or machine method in terms of its effect not only upon the particular operation in question, but upon the entire farm organization.

While I have outlined for you primarily the "large farm" aspects of this problem, we appreciate fully the hinderances preventing any rapid adoption of a program of this kind in our state. However, we wish to try to establish the true merits of the proposition. If meritorious, it will serve as a long-time objective. We are also giving as much or more time to the problems of efficient machinery use on smaller farms, but unfortunately we are not in a position to report anything of particular importance at this time.

Agricultural engineers have developed splendid agricultural equipment, and in conclusion I submit the proposition that it is their job, mainly, working in close cooperation with economists and all other departments and agencies of agricultural production, to develop the proper use and coordination of this equipment to the entire farm business, in the final interest of increasing profits and adding satisfactions to farm life.

A Proposed Engineering-Economic Policy for Agriculture[1]

By James A. King[2]

THE PROGRAM which I wish to propound may seem to be more economic than engineering. But, to be sound, any engineering program must start from a sound economic basis. And a good engineer always first sees that his bench mark is correct and that his objective is logical and worth while.

This is the bench mark of my proposed plan: Agriculture is the foundation on which the world's economic and social structure is built. Therefore, the future growth and development of the world's economic and social structure will be limited by the world's agriculture.

Here is the objective contemplated in my proposed plan for agriculture: A farm culture that will guard and conserve those basic personal and group virtues which are subjected to such severe stress and trial by life in the towns and cities, which renew their population from our farms.

An agriculture whose products have an equitable exchange value in the markets of the world, so that a given amount of ability and effort will bring to the agricultural worker a measure of economic values commensurate with that obtained from an equal amount of ability and effort expended in other activities.

The general plan which I propose for starting from this bench mark and arriving at that objective involves the following major factors:

1. A change in our customs of land ownership toward these objectives:

   (a) Owner operation, rather than tenant operation.

   (b) Less frequent payments for the land out of the income from the land itself, so that more of the earnings can be used for maintaining, and even increasing the operating equipment and the productivity of the land.

   (c) Long term amortization of mortgage debt with reasonable provision for refinancing occasional unavoidable defaults in payment of installments. This would give the owner greater security in the continued possession of his land, with the resulting greater incentive to maintain his improvement program.

2. A constant effort to reduce the unit costs of production. Regardless of what the market price may be, the man who produces at the lowest unit cost has the best chance to sell at some profit, and always sells at the longest profit. Only very broad, general rules can be laid down that will prove applicable to all types of agriculture and to all individual farms. But, these should include keeping at a minimum all fixed overhead costs and all human labor per unit of production.

3. Not only maintaining, but also actually increasing the fertility of the soil of the farm to make safe the financial and the human investment in that farm. In this connection, I would lay special stress on erosion control by terracing and by contour planting of all cultivated crops on all rolling land, and on the draining of all clay and clay-loam soils.

4. Greater efficiency and durability of all structures, improvements, and equipment, with their cost figured on the basis of their annual cost per unit of product produced or housed, rather than simply on the basis of their initial cost.

5. Decentralization of industry to give a local market for a larger percentage of farm food products.

6. Greater stability of consumer income to give greater stability to farm prices. As an aid to this end I would urge industry to adopt a voluntary plan of unemployment insurance and old age retirement on part pay.

7. A further development of industries that use annual farm crops as their raw material. This will give employment to tillable land that is not required for the production of food. It has been suggested by one agricultural engineer that all gasoline used be diluted by adding 3 per cent of alcohol. What this would mean to agriculture is shown by the fact that, if all the crops produced in America were made into alcohol, it would not be enough to replace our annual consumption of gasoline.

[1]A contribution to the discussion of "An Engineer's Policy for Agriculture" at the 26th annual meeting of the American Society of Agricultural Engineers held at Ohio State University, Columbus, in June 1932.

[2]Advertising and publicity manager, Mason City Brick and Tile Company. Mem. A.S.A.E.

The Dynamic Properties of Soil[1]

IV. A Method of Analysis of Plow Moldboard Design Based upon Dynamic Properties of Soil

By M. L. Nichols[2] and T. H. Kummer[3]

ALTHOUGH the plow is generally considered the most important implement of tillage, there has been no satisfactory and usable theory of design available. Studies of physical properties of soils [4, 5, 6] have shown that there are laws, which govern their reactions and which are expressible by mathematical formulas. The reactions of all soils are similar in nature though they vary quite widely in force values. It is concluded from these facts that, although the plows had been designed empirically, there must be some general mechanical principles embodied in successful plow design to meet these soil requirements, and that these design features could be expressed by mathematical formulas.

The reactive properties of soil to moldboard curvatures were studied[4] (1) by observation of plows in the field, (2) by observation of small plows run in the laboratory in glass-sided boxes, containing various soils in different conditions, and (3) by measurement of the reaction of soils to various chisel shapes approximating sections of a moldboard. Studies were then made of moldboards by two sets of perpendicular differential sections, one parallel with and the other at right angles to the landside, and then by spiral differential sections. It was found that the kind and degree of curvature could be explained by means of the soil reaction data and the entire surface expressed by simple mathematical formulas.

This paper includes a discussion of the general principles of design, a method of measuring and expressing moldboard shapes mathematically, and the general relationship of these curvatures to the dynamic properties of the soil. In order to present these findings in the most understandable manner, the authors have organized this paper in the order of the steps taken in this investigation as a logical approach to this problem.

The relationship of formulas to soil types and speeds of plowing is indicated, but sufficient data is not yet available to evaluate the constants necessary for the design of moldboards to fit various soil conditions at different plow speeds. Many other plow problems such as coverage, suction, landside pressures and scouring are undoubtedly closely related to the curvature of the moldboard, but to establish the exact nature of these relationships additional data must be secured.

MECHANICAL FUNCTIONS OF A PLOW

Classification. The mechanical functions of a plow may be classified by its action on the soil. These primarily are

1. The breaking or cutting loose of the furrow slice
2. The pulverization of the furrow slice
3. The inversion of the furrow slice
4. The covering of trash and weeds

Eliminating such factors as landside pressure; wing, point, and heelbearings; suction, and other features of stability and smooth running, this classification centers attention on the moldboard, shin, and share action. The entire surface of the moldboard side of the plow acts as a unit, and no distinction will be made in this discussion between the different parts manufactured as separate units of construction.

[1]Fourth of a series setting forth the results of ten years of original research work in soil dynamics at the Alabama Agricultural Experiment Station. This paper is a report of cooperative work between the Alabama station and the Bureau of Agricultural Engineering, U. S. Department of Agriculture. Parts I, II and III were published in the July 1931, August 1931, and August 1932 numbers of AGRICULTURAL ENGINEERING, respectively.

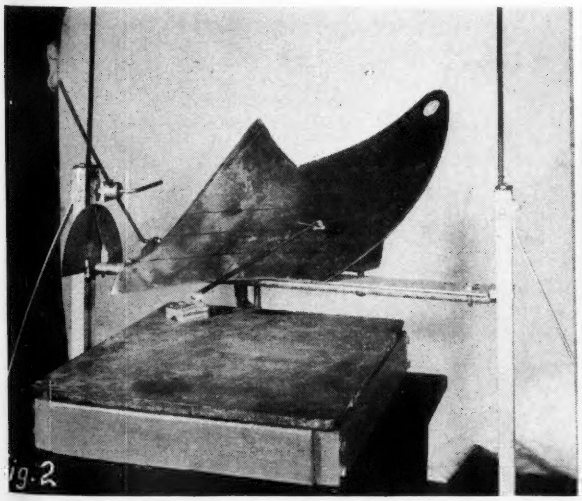
[2]Agricultural engineer, Alabama Agricultural Experiment Station. Mem. A.S.A.E.

[3]Graduate student in agricultural engineering, Alabama Polytechnic Institute.

[4]Nichols, M. L. Methods of Research in Soil Dynamics, Alabama Station Bulletin No. 229, May 1929.

[5]Nichols, M. L. The Dynamic Properties of Soil, I. An Explanation of the Dynamic Properties of Soil by Means of Colloidal Films. AGRICULTURAL ENGINEERING 12: 259-264, 1931.

[6]Nichols, M. L. and Baver, L. D. An Interpretation of the Physical Properties of Soil Affecting Tillage and Implement Design by Means of the Atterberg Consistency Constants. Proceedings of International Soil Congress. Leningrad, Russia, Section 1, 1930.



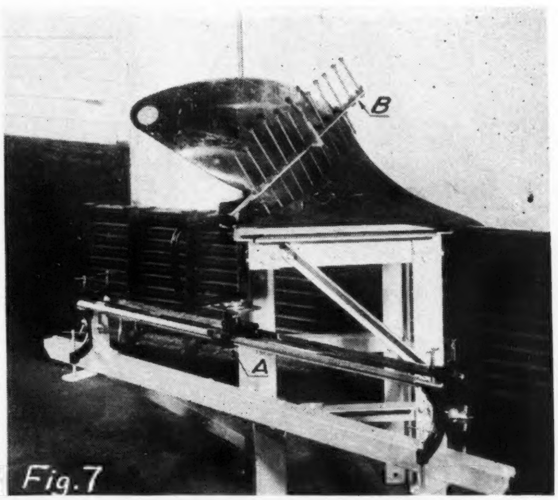


Fig 2. Apparatus for laying off vertical differential sections. Fig 7. Apparatus for measuring moldboard surfaces

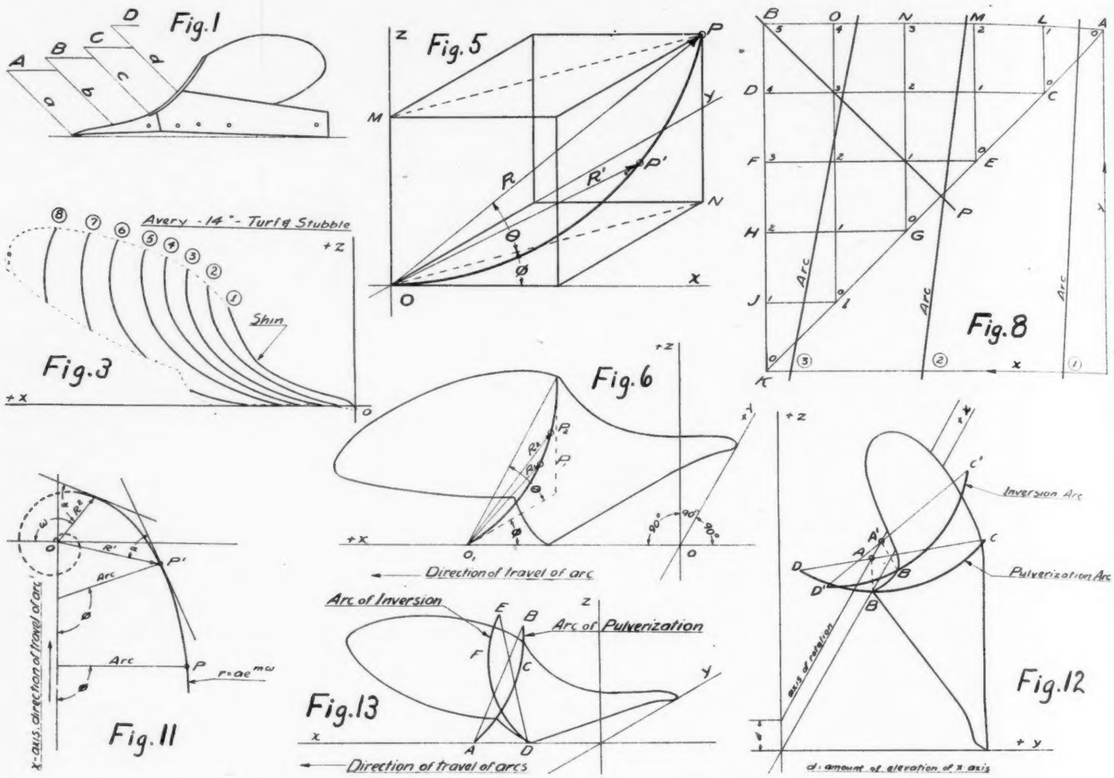


Fig 1. Diagram showing the reaction of soil as a plow advances through it. Fig 3. Pantograph copy showing the curvature of differential sections parallel with the plane y = O. Fig 5. Method of locating arc by polar coordinates. Fig 6. Diagram showing method of measuring moldboard surface. Fig 8. Projection of section of pulverization area on plane z = O. Fig 11. Diagram showing by horizontal projection the nature of the curved path of travel of a soil particle on the moldboard and its relation to the travel of the arc describing the plow surface. Fig 12. Diagram showing the effect produced by elevating the path of travel of the arc describing a plow's surface. Fig 13. Diagram showing method of fitting the special inversion arc required to describe the surfaces of some plows

Relation of Functions to Design. The mechanical functions listed above are arranged in the sequence in which they occur in the passage of the plow through the soil. The breaking or cutting loose of the furrow slice must occur at the share edge and shin. The pulverization may be largely confined to one portion of the plow surface or extend throughout the entire moldboard. Lifting and turning extend throughout the plow length, but the rate of turning generally increases on the upper and rear parts of the moldboard. This is borne out by the "full-cut" section of Ashby[7]. The covering of weeds and trash for any particular size of plow is a function of turning and inversion. The relationship between speed and throw of soil and moldboard pressures is dependent upon moldboard curvature. The laws expressing the relationships between these functions and the moldboard shape or curvature should furnish a satisfactory basis of design.

A STUDY OF PERPENDICULAR DIFFERENTIAL SECTIONS

Theory of Pulverization and Uniform Pressure Surface. The reaction of a soil to an advancing surface[4] will be discussed here as a basis for explaining the pulverizing action of the plow. As the plow moves forward through the soil, the pressure produced by the moldboard's advance compresses the soil upward and forward. When the resistance to the compression exceeds the shear value, the block of soil is sheared off at an angle of approximately 45 deg with the horizontal and slides up the shear plane as a solid unit. The forward movement of this block is due to the friction of the soil and metal and continues until the resistance of the soil ahead of the block becomes equal to or greater than the friction between it and the metal, when the soil slides upward on the metal surface. As the plow moves forward, another shear plane is developed, and another block of soil is broken loose which follows the first up the moldboard with similar movement on its shear plane and the plow surface. These reactions may best be understood by observing soil movements in front of a section of a moldboard moving through soil in a glass-sided box. A diagram of these reactions is shown in Fig 1. This shows the soil divided into layers or blocks by the shear planes which develop at regular intervals in a uniform soil due to the pressure of the advancing point and share. The blocks of soil arrange themselves to conform with the shape of the moldboard. Movements on all shear planes would occur simultaneously if the correct curvature were given the plow surface. This simultaneous movement throughout the mass would produce pulverization.

A mathematical expression for the curvature necessary to produce this effect may be deduced from a study of Fig 1. As the plow advances, the soil slips over itself on shear plane "a". To keep the soil slipping over itself in plane "b" at the same rate as the movement on "a," the block B must travel forward at the same rate as the block A, plus an additional amount equal to the movement of A. To keep the soil block "C" slipping over B on the shear plane "c" at the same rate as the movements on "a" and "b," the block C must move an amount equal to the combined movements of A and B plus the

[7]Ashby, Wallace. Progress Report on Plow Investigations for Corn Borer Control. U. S. Department of Agriculture.

additional amount of the movement of A. The movement of the successive blocks of soil continues in this manner throughout the pulverization portion of the moldboard. This means that the movement throughout the soil mass on all shear planes is equal, that the total forward and upward motion is progressing with constantly increasing velocity as the soil slips up the plow, and that pulverization by shearing is taking place throughout the mass of the furrow slice. This is equivalent to the statement that the soil is being constantly and uniformly accelerated in a forward and upward direction as the plow advances.

Constant acceleration is an important consideration in plow design, because constant or uniform acceleration means that a constant pressure is being applied to the soil by the moldboard. This is a necessary condition for uniform scouring and wear. For the purpose of clarification, a comparison may be made between this action and the acceleration of a particle falling in space under the force of gravity. Gravity, a practically constant and uniform force, produces a constantly increasing velocity in a falling particle. The velocity is a function of the distance traveled, while the pull of gravity exerted on the particle, or the acceleration, is constant. If in the case of the plow the velocity or the forward and upward travel of a block of soil is increasing at a constant rate, it follows that the soil has constant and uniform acceleration and the motion is produced by a uniform pressure.

The curvature of a vertical differential section of a moldboard which keeps the soil slipping on all shear planes simultaneously and uniformly must be constantly increasing at a rate which is proportional to the distance traveled up the curve. A mathematical statement of this relationship is that the rate of the increase of the z-coordinate per unit of increase of x must be proportional to z, that is,

$$\frac{dz}{dx} = abe^{bx} = bz$$

This indicates that a vertical differential section of the moldboard parallel with the landside should have the formula

$$z = ae^{bx}$$

where z and x are the coordinates of the curve, e the base of natural logarithms, and a and b constants. This is the formula expressing the well-known "compound interest law" so frequently occurring in nature.

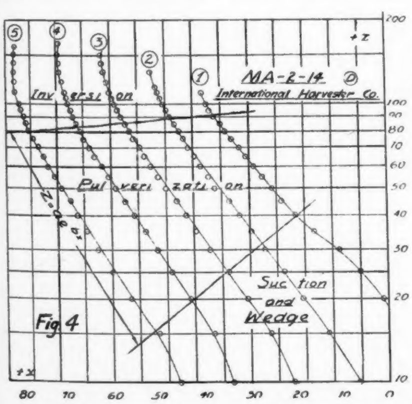
Confirmation of Theory. To determine if common plows conformed with this theory, a number of typical successful plows, Table I, were obtained from manufacturers and studied. The curvatures of various differential sections were determined as follows: The plow was fastened to an adjustable rack, Fig 2, so that the landside was horizontal. The intersections of various horizontal planes were then marked on the moldboard by a gage moving on a horizontal surface plate. These lines were in most cases practically parallel with the shin of the plow, varying only with the landside suction. The curvatures of these intersections were taken from the plow by means of a pantograph and a camera-lucida; however, the pantograph method was found to be more accurate as it eliminated the optical error of the camera-lucida.

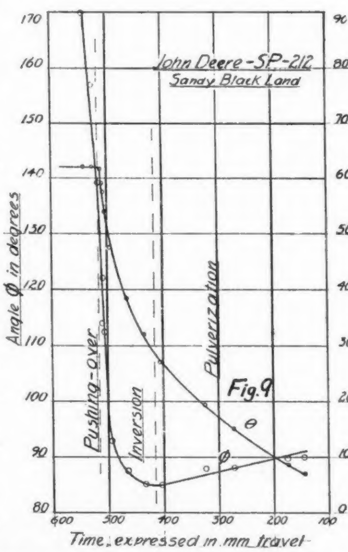
The curves shown in Fig 3 are typical of those for all plows studied. It was found by plotting these curves on semi-logarithmic paper, Fig 4, that major portions of them could be fitted by the formula, $z = ae^{bx}$. The constant a indicated the location of the differential section, and the constant b denoted the degree of pulverization or steepness of the slope of the section. In all cases the lower portion of the curve varied from the formula. It was found that this portion of the plow was varied for increased mechanical strength and suction. The increased steepness of the point and of the cutting edge of the share also serves to break the soil loose at the bottom of the furrow slice and by wedge action throws the first shear plane out in front of the moldboard. Normally this plane was found to have an angle of 45 deg with the horizontal. The shear plane must be broken from undisturbed soil which requires greater force than that necessary for subsequent movements on this plane. The force required for slipping on the different shear planes, once they are broken loose, should be practically a constant, thus permitting a uniform pressure throughout the moldboard surface above the shear or wedge area. The variation of the upper part of the curves from the formula, as shown in Fig 4, is due to the curvature of the surface for turning.

PRELIMINARY INVESTIGATION OF INVERSION

Turning in the Pulverization Area. The angle made by the cutting edge of the share varied from 40 to 50 deg for different plows, measuring in most cases approximately 45 deg. The differential sections shown in Fig 3, therefore, which are contours measured on the moldboard when the plows are lying on the landside, start at points progressively set towards the rear of the plow by uniform distances, thus giving the characteristic triple-wedge formation of the common plow. This construction causes the part of the furrow slice near the shin to be raised a considerable distance before the wing side of the slice is elevated. The turning and inversion movements start immediately upon the breaking loose of the soil.

Since on all plows the point is advanced a considerable distance in front of the share, the formation of





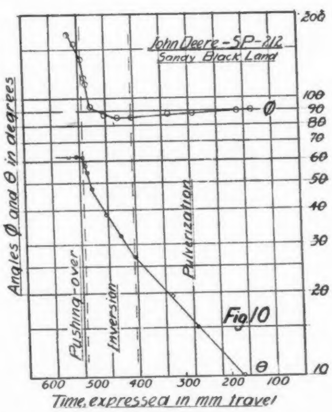


Fig 4. Curves shown in Fig 3 plotted on semi-logarithmic paper. Fig 9. Graph showing the variations in position of the arc while sweeping out a plow surface. Fig 10. Data shown in Fig 9 plotted on semi-logarithmic paper

the first shear plane starts at the front and is extended across the furrow at a uniform rate of advance. The angle of 45 deg is approximately that of the normal shear angle of soil and should, therefore, give the least draft resistance with maximum pulverization. The width of cut of the share introduces a question of considerable importance. In some plows the cutting edge of the share extends only over a portion of the width of the furrow; in others, for example the sod-breaker plows, the share extends into the preceding furrow. Further experimental work must be done to determine the differences in draft, pulverization, and coverage due to different angles and lengths of shares. This will affect moldboard shapes, but not the principles set forth here, as will be shown later.

Turning on the Upper Moldboard. Most of the turning is accomplished by the upper part of the moldboard. A preliminary study of the curvature was made with an adjustable curve-ruler to determine how this was accomplished. This ruler was so constructed that it could be pressed down on the plow surface and would retain its curvature. It was found that one particular curve could be slipped over the entire upper moldboard of each plow studied and fit the surface continuously. On many plows the same curve fitted both the upper and the lower portion of the moldboard.

It was observed that the fitted curve-ruler would fit the entire surface when grasped at the place where it fitted the point of the wing and the hand holding it was rotated as it moved to the rear in the line of travel of the wing. It was concluded from this observation that the entire surface could be expressed mathematically by polar coordinates. This method of measuring and expressing the curvatures of the plow surface was found to be adaptable to all plows studied. A detailed description of the method and principles involved follows.

A METHOD OF EXPRESSING A MOLDBOARD SURFACE MATHEMATICALLY

It was considered necessary that some form of expressing the relationships of the different parts of the plow surface be found. This would logically be an integration of the differential sections. It was decided to study the entire surface by applying the basic principles of integration by some mechanical device, rather than to attempt the complicated and tedious process of a formal mathematical study by differential sections in two directions. Such a method of describing a surface may possibly be criticised by mathematicians, but it was found to have the advantage of accurately describing the surfaces of all the plows studied in a simple manner which can be used more easily by the designer than a complicated integral formula. The same mechanism can also be used for the design and inspection of moldboards.

Method of Locating a Point in Space by Polar Coordinates. The location of any point in space may be expressed by polar coordinates as follows: Take three rectangular axes, x, y, and z, as in Fig 5. Let P be the point, and join O and P. Let a plane through OP and Oz cut the plane Oxy on ON. Draw PN perpendicular to the plane Oxy and PM perpendicular to Oz. The rectangular block whose edges are the rectangular coordinates, x, y, and z, is thus cut by a diagonal plane in a section which is the rectangle ONPM. The polar coordinates of P are

1. The distance r of P from the origin
2. The angle between OP and the axis of z, or its complement, angle θ
3. The angle ϕ between the plane OPN and the axis of x.

If desirable the polar coordinates may be converted to rectangular coordinates by the formulas: $z = r \sin \theta$; $x = r \cos \theta \cos \phi$; $y = r \cos \theta \sin \phi$.

Application of Method to Plow Surfaces. The movement of a line in space describes a surface. If R, Fig 5, is the chord of the arc OP′P of a given curve, variations of the angles ϕ and θ, produced by movements of the chord, will cause the arc to sweep out a surface. Since the relationship of the chord R and the arc remains constant, the position of any point P′ of the arc in space at any time may be described by the angles ϕ and θ and the relationship of the point to the chord R.

It was previously stated that the entire surface of the plow could be fitted with a single curve which moved and rotated on the line of travel of the tip of the wing of the share. Taking this line as the x-axis, Fig 6, and placing the plow on the plane $z = 0$ with the point of the wing on the x-axis, the landside parallel to this axis, and the point of the plow on the y-axis, the entire upper moldboard surface may be described by moving the chord with its fixed arc along the x-axis and recording the distance traveled and the angles ϕ and θ. This mathematically would involve a constant shifting of the coordinates along the x-axis and produce formulas complicated by continuous translocation of axes. If, however, the plow is moved forward at a uniform rate, the axes may remain stationary and the form of the surface be described by the angles θ, ϕ, and time. As the distances moved in this case are directly proportional to time, the measured numerical value of distance moved along the x-axis may be substituted for time as coordinate and mathematical complications arising from translocation of the axes avoided. Thus, when the relationship between the chord and the arc is determined, the entire surface may be described by parametric equations which show the relation of ϕ, θ, and time. In these equations ϕ is the angle between the plane of the chord and arc and the plane $y = 0$; θ is the angle between the chord and the horizontal, and t is the distance the plow has moved forward.

It is possible to combine the arc formula and values of ϕ, θ, and t into one formula expressing the entire surface of the plow. This would give a formula for each particular plow, but in the author's opinion it would add nothing to the usableness of the findings and tend to complicate rather than simplify mathematical study. This is particularly true because in many plows, as will be shown later, the pulverization and inversion sections are swept out by two different curves.

Apparatus for Measuring Moldboard Curvature. The apparatus shown in Fig 7 was designed and built to deter-

Table I. List of Plows Studied

No.	Manufacturer	Manufacturer's designation	Size, inches	Material
1	International Harv.	KA-1-14 (E)	14	Steel
2	International Harv.	HA-1-14 (E)	14	Steel
3	International Harv.	F-1-14 (E)	14	Steel
4	International Harv.	MA-2-14 (D)	14	Steel
5	International Harv.	GA-1-14 (E)	14	Steel
6	International Harv.	N-2-M-14 (E) Special	14	Steel
7	International Harv.	CP15003H-MBB2-14 (F)	14	Steel and chilled iron
8	International Harv.	Slat. 92B-HR	9	Steel and chilled iron
9	International Harv.	MH-1-12 (C)	12	Steel
10	B. F. Avery & Sons	10M	10	Steel
11	B. F. Avery & Sons	31	9	Chilled iron
12	B. F. Avery & Sons	Texas	14	Steel
13	B. F. Avery & Sons	Stubble	14	Steel
14	B. F. Avery & Sons	Turf and stubble	14	Steel
15	B. F. Avery & Sons	Paragon (left hand)	16	Steel
16	John Deere	MP212	12	Steel
17	John Deere	BR-20	10	Steel
18	John Deere	SP-212	12	Steel
19	John Deere	Slat	12	Steel
20	Oliver	NC3F	18	Steel
21	Oliver	NC23	14	Steel
22	Oliver		12	Chilled iron

mine the values of ϕ, θ, and t for various plows. It consists of a surface plate on which the plow is held in its normal position when running in the field. A slider, A, is mounted on a track parallel with the landside of the plow. This slider supports an arm, B, which is the chord of the arc previously described. The chord arm, B, is hinged at one end between two guides at the same elevation as the point of the wing permitting the loose end to swing up and down. The plane of the chord and arc is always held perpendicular to the plane $z = O$ by the guides. The angle θ is measured by a protractor and plumb bob, while the angle ϕ is measured by another protractor on the slider. The guide track is marked in millimeter divisions. The entire track can be raised or lowered, and in operation is adjusted to a horizontal position by means of a spirit level.

Brass screw rods are tapped in the chord-arm. These are adjusted to the plow surface and locked in place by double lock nuts. The screw rods are spaced 1½ in on centers and, when adjusted so that the points fit the plow surface, give eight or nine points on the arc of the curve whose motion sweeps out the surface of the plow.

Fitting Plow Surfaces. The surfaces of all the plows listed in Table I were studied by means of this apparatus, and it was found that all could be described by this method. The maximum error throughout the moldboard was 1/16 in for the majority of the plows studied. The plows were fitted by trial and error. It was found that one curve would sweep out the entire surface of sod plows and the plows adapted to heavy, sticky soils; but that two different curves were necessary for some of the very steep stubble and general-purpose plows, one curve fitting the pulverization section of the plow and the other fitting the turning and inversion portion.

When the correct curve was found, the apparatus was then started at the point of the plow and moved along its surface. At intervals the respective changes of ϕ and θ angles and distance traveled were recorded, thus obtaining the polar coordinates of the chord and their variation with time for the description of the plow surface. It was found that the screw points of the apparatus traveled exactly in the path of the soil travel as shown by scouring scratches on used plows. On examining used plows it was found that in areas where the points did not touch the surface the plow did not scour, and where high places were found excessive wear occurred. Projections of the travel of these points also agreed with the projections of soil travel as recorded by White[8].

Arcs Describing Plow Surfaces. After the above-described measurements had been taken the entire chord-arm was removed from the apparatus to determine the relation between the curve and the chord whose position was described by the coordinates ϕ, θ, and time. In every case the curve was found to be a section or arc of a circle. The radius of this circle was obtained by means of trammels. In most cases the arc passed through the hinge of the chord-arm which moved along the x-axis. The exceptions to this will be explained later under methods of inversion.

The fact that surfaces whose differential sections were fitted throughout the pulverization area by the formula $z = ae^{bx}$ were swept out by the arcs of circles required explanation. The conclusions from a study of this feature of design follows:

In Fig 8 the lines AB, CD, EF, GH, and IJ represent the projections of the differential sections of a portion of the pulverization area of the moldboard on the plane $z = O$. The planes of these sections are parallel with the landside of the plow. The line AK is parallel with the cutting edge of the share which on all plows is in the plane $z = O$. The curve of which AB is the projection has the formula $z = ae^{bx}$, and similarly CD, EF, GH, etc., are projections of curves of the same shape differing only in location with reference to the y-axis as previously explained.

[8]White, E. A. A Study of Plow Bottoms. Thesis for doctorate degree, Cornell University.

The spaces between the differential sections, shown in Fig 8, are equal, and the horizontal distances between points 1, 2, 3, etc., on the respective curves are the same as the distances between the sections. Since the curves from which the lines are projected are identical, it follows that the points on the curves above the points 1, 2, 3, etc., for each line have elevations corresponding to the number of the point. For example, every point designated by the figure "2" would have the same elevation as every other point designated by the same figure. Therefore, differential sections of the surface whose projections are represented by lines CL, EM, GN, IO, etc., would have formulas similar to those of sections taken in the direction of AB, CD, etc., that is, these formulas would have the form $z = ae^{bx}$. Fig 8, which represents a portion of the pulverization area of the moldboard, would then be symmetrical with respect to the line BP. It is logical to expect and is shown that differential sections in the direction BK should follow the same laws as differential sections in the direction AB. It was deduced from Fig 8, and checked on the plows, that a surface of this nature would have straight lines joining points of the same numerical designation.

Since the curves represented by the projection AB, CD, etc., are identical, except that they are set back progressively from the y-axis, it follows that the areas represented by integrals of the surfaces ACDB, CEFD, EGHF, etc., are also identical in shape but vary in their distance from the y-axis. If the entire section of the surface, composed of a group of integral surfaces, is swept out by a single curve moving along the x-axis so that it occupies the positions 1, 2, and 3 successively, the same curvature would be required of the section of the curve which swept out the surface of ACDB as the curvature of that section which swept out CEFD. Likewise all succeeding sections must have the same curvature to sweep out similar surfaces. If these areas be taken of smaller and small widths with the same reasoning, it will be seen that the curvature of the line must be constant throughout. This means that the curve must be an arc of a circle. The slope or steepness of a curve having the formula of the differential sections is, however, constantly increasing, and the time of sweeping out successive differential sections is progressively delayed as their distance from the x-axis decreases. These conditions are met by rotating the arc around the x-axis. Since the curve AB is a constant-acceleration curve, the arc is being rotated around the x-axis with constant acceleration, that is, $Ln\ (\theta \div c) = ht$. This was found to be the case for all plows, an example of which is shown in Figs 9 and 10. The relationship between the formulas for the differential sections, $z = ae^{bx}$, or $Ln\ (z \div a) = bx$, and the formulas for the rotation of the arc, $Ln\ (\theta \div c) = ht$, may be more easily seen when it is recalled that t and x are synonymous expressions for travel along the x-axis and that $z = r \sin \theta$.

It has been shown that the vertical differential sections in planes parallel to the plane $x = O$ have the formula $z = ae^{by}$, and that the arc of a circle could be moved along and rotated on the x-axis to describe the surface. This is explained as follows: The curvature of each of these sections, having the formula $z = ae^{by}$, is constantly changing. Each section is similar in form but varies progressively in its distance from the x-axis. It would, therefore, be possible to select successive adjoining points along the surface to form a line of constant curvature which would be the arc of a circle. This arc would never be in a plane parallel with the plane of the sections but at an angle (ϕ) with them. The rate of change of the angle ϕ, as the arc slips up the moldboard, varies with different values of the constant b in the formulas of the vertical differential sections of different plows. Since the layers of soil are constantly slipping over each other at a rate dependent on the constant b in the same formula, the angle ϕ must be constantly decreasing at the same rate through the pulverization area, so that the plow will always be pressing on the soil. The rate of the decrease of ϕ with t through this section would be logarithmic. This was found to be the case as shown in Fig 10.

The establishment of the relationship of the differential seetions and the method of describing the surface to the reactions of soil gives a basis for the design of the pulverization part of the moldboard.

STUDY OF SPIRAL SECTIONS

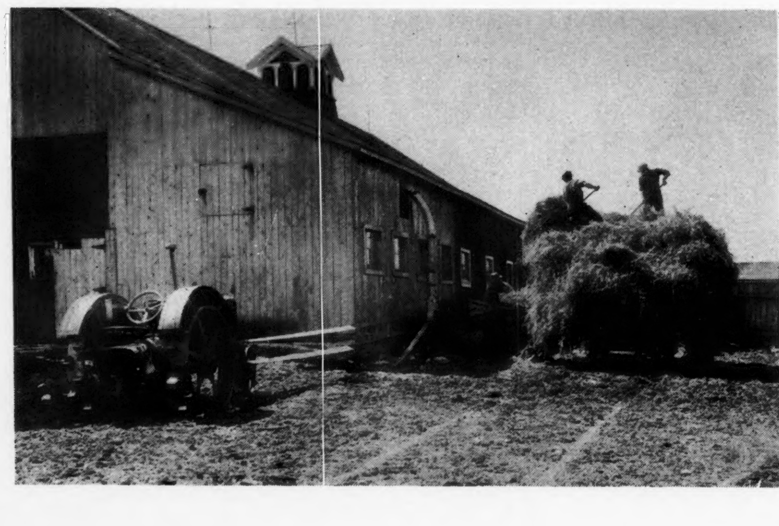
Turning and Inversion on the Upper Moldboard. In the upper moldboard the inversion process, started in the pulverization area, must be completed and the soil thrown to the right into the preceding furrow. During this process it is necessary that for uniform scouring the inversion area also should have a uniform pressure.

It has been shown that arcs would sweep out or cover the entire moldboard when rotated and moved along a line running through the tip of the wing parallel with the landside. The rotation of these arcs was studied by plotting time as the abscissa and ϕ and θ as ordinates. Fig 9 shows the results for a typical plow. Upon plotting that data on semi-logarithmic paper, Fig 10, it was found that each curve was divided into a series of straight lines. All steel plows studied followed this law closely. The data from chilled-iron plows, which were designed for sandy soils or easy-scouring conditions, showed considerable deviation from any regular line when plotted on semi-logarithmic paper. This data, however, appeared to fit straight lines more closely than any other regular curve. These findings indicated that a uniform-pressure curve was also used for inversion and turning. This may be explained by its analogy with the easement spiral or transition curves used in railroad or highway engineering, in which the angle ϕ indicates the turning curvature and the angle θ the banking or superelevation.

The data of the curves showed that this easement was produced by a logarithmic or equiangular spiral corresponding to the path of the soil travel on the plow surface. This is a curve such that the angles between its tangents and the corresponding radii, drawn to the center of the curve, are equal. This is shown in Fig 11 which is a projection of this spiral on the plane $z = O$. This projection enables turning to be studied independently from superelevation. The polar equation of the curve is $r = ae^{m\omega}$, where a is the value of r when $\omega = O$ (ω is measured in radians) and $m = \cot \alpha$, α being the constant angle of the spiral. It will be seen that the soil slipping around a section of the moldboard having a curvature of this formula would be changing direction constantly. The turning acceleration would be constant, for as the soil travels around the curve the angle α is constant. A constant or uniform turning acceleration should give equal pressures throughout the curve. If this is true for any differential section, it follows that it is true for the entire upper moldboard. This can be more easily seen when it is remembered that the soil travels around the upper moldboard as a pulverized mass.

It is necessary to show the relationship of the spirals whose horizontal projections have the formula $r = ae^{m\omega}$ to the ϕ, θ, t curves which were used in describing moldboards. This relationship can be studied by projections on the plane $z = O$. In Fig 11 let the point O, which is the center of turning of the spiral, lie on the x-axis, and ϕ be the angle between the projection of the measuring arc and the x-axis. The spiral represents the horizontal projection of the path of a soil particle, P, traveling on the surface of the moldboard. This projection has the formula $r = ae^{m\omega}$. This is equivalent to stating that the soil is turning around the point O on a curve whose radius is decreasing logarithmically with the angle of turning; that is, the logarithm of the radius is proportional to the angle turned, or $Ln\ (r \div a) = m\ \omega$. The point P, which is also a point on the rigid arc held at a constant distance from the x-axis, therefore, must swing towards the x-axis at a rate proportional to that at which the radius decreases. This means that in the turning portion of the plow the angle ϕ increases logarithmically as the chord arm and arc travel along the x-axis. This was found to be the case as shown in Fig 10. A mathematical expression of this statement is $\phi = \rho e^{kt}$, where ϕ and t are angle and distance of travel, and where ρ and k are constants governing the rate of turning or throw of the plow. It is obvious that variations of the angle α in the equiangular-spiral formula would produce corresponding variations in the throw of the plow.

It will be noted, Figs 9 and 10, that the curve of θ and time represents the inversion of the furrow slice. The ϕ-t and θ-t curves have a definite relationship. In the lower or pulverization section this relationship has already been explained as being due to the slipping of the arc over a surface whose differential sections have the formula $z = ae^{bx}$. On a few plows, for example Plow No. 9 Table I, this relationship was carried nearly throughout the entire moldboard. Others have decided breaks in the θ-t curve, Fig 10, as shown by the slopes of the lines when plotted on semi-logarithmic paper. These breaks or changes of slope correspond with those of the ϕ-t curves. It was concluded that this relationship was due to the necessity of producing in the inversion and turning portion of the moldboard an increase in elevation for the upper parts similar to the elevation of the outside of the roadbed on a curve. In a properly designed roadway a freely steering car will turn itself around the curve if running at the speed for which the road was designed. The elevation in this case is proportional to the degree of turning. This is analogous to the condition occurring on the plow as shown in Fig 10. Since the easement curve (ϕ-t) is loga-



A Modern Way of Handling the Hay Crop

The chopping of hay as a convenient and economical method, not only for storing it but also for subsequent feeding to livestock, is rapidly gaining favor. The unit shown here, consisting of a Case silo filler and tractor, is at work on a modern dairy farm in Wisconsin. Three men can unload, chop, and blow into the mow a good sized load of alfalfa in 12 to 15 min. The chopped hay requires about 60 per cent of the storage space required by loose hay

rithmic, the inversion or bank curve (θ-t) is also logarithmic.

It will be noted that there are two decided breaks or changes in each extreme upper end of both the ϕ-t and θ-t curves. This is due to the fact that in this part of the moldboard the soil is no longer sustained by the moldboard and gravity is acting on the soil. The moldboard then must be still further accelerated to keep up with the soil. Another change in the direction of the curve occurs after the soil has fallen to the ground. Field observation of the action of this part of the moldboard on many plows shows that this extreme outward portion of the moldboard is pushing on the soil after the lower part has fallen to the ground, thus pushing or knocking it over to complete the inversion process. On many plows this action is further insured by an extension made by bolting a rod or bar on the tip of the moldboard.

The general principles of moldboard design for inversion set forth above were found to hold in all cases. It was found that there were three methods of accomplishing inversion for different conditions. These are as follows:

Method of Design for Tough or Sticky Soils. In this case the moldboard is designed so that the arc is rotated around a point which travels along the x-axis as above described.

Method of Design Common for General-Purpose Plows. For steeper or shorter plows a more rapid method of inversion is necessary. In this case the arc of the circle is rotated around a point which travels along a line parallel to and directly above the x-axis. This is shown in Fig 12. When the axis of rotation is above the x-axis, the arc is rotated around this axis on a point A in the chord-arm between its ends C and D. At the point of the wing the point B of the arc passes through the x-axis, but as it is rotated in inversion, point B swings in, forming the waist of the plow.

Method of Design Common for Stubble Plows. For still more rapid inversion the upper part of the moldboard or inversion section may be swept out by an arc of a smaller radius than that of the pulverization arc. This is shown in Fig 13 where ABC is the arc of pulverization area and DEF the arc of the inversion area. An explanation of how the surfaces, formed by the movement of two arcs having different radii, may be fitted together smoothly without breaks may help to clarify this point. The protection of two arcs having two chords of the same length but different radii may be made identical by rotating the arcs around the chord. If the plane including the chord and arc is rotated on the line of the chord so that the plane changes from a position parallel with the plane of projection to a position perpendicular to it, the curvature of the arc's projection changes from the section of a circle to a straight line which is an arc having a radius of infinity. The projections of any two arcs having chords of equal length may thus be made to coincide. To fit a smaller arc to a plow surface formed by the rotation of a larger arc, the smaller one then must be oriented until it perfectly fits the surface. This was found to be necessary in fitting some of the steeper moldboards as shown in Fig 13. It is apparent that the action of these moldboards on the furrow slice differs slightly from that of the moldboards described by one arc because the relative positions of soil particles must be changed to fit the second arc. The change of relative position produces an additional bend or throw which speeds up inversion. This involves a difference of pressures between the lower and upper moldboards, and it is significant that this feature of design was only found on plows built for rather easy scouring conditions. It was found that combinations of these three methods of inversion were used in designing plows for different soil conditions.

VARIATIONS IN APPLICATION OF PRINCIPLES TO DESIGN

While the general principles set forth for pulverization, turning and inversion were found to apply to all plows studied, there is a wide range of possible applications. This may be shown by two plows of rather uncommon design which were studied. The first, No 7, Table I, is a 14-in plow whose share does not extend the entire width of the furrow. In this plow the axis of rotation is at the point of the wing and approximately 1½ in from the furrow wall. To completely free the furrow slice from the bottom of the furrow the uncut portion must be broken loose. In turning, this portion may adhere to the furrow slice and be completely inverted, or it may fall to the bottom of the furrow and be covered by the next furrow slice. The turning on a point inside the furrow slice, in this case 1½ in from the furrow wall, involves an additional twisting of the slice. The second plow, No 6, Table I, is designed for stiff sods. It has a share that extends into the preceding furrow, thus insuring the cutting of all roots. The axis of rotation for this plow which is in line parallel with the landside lies between the wing tip and the point. In this case the entire furrow slice is lifted by the share before turning.

SUMMARY

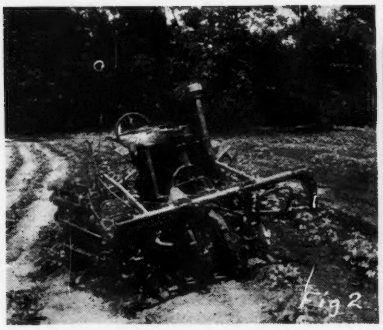
The moldboard curvatures of a group of typical plows were studied in relation to soil reactions and to the general functions of breaking-loose, pulverization, and inversion of the furrow slice. In general all moldboards were found to be functionally divided into three sections, as (1) the lower or share portion, forming a wedge for breaking the soil loose, (2) a central pulverization area, and (3) a turning and inversion area on the upper part of the moldboard.

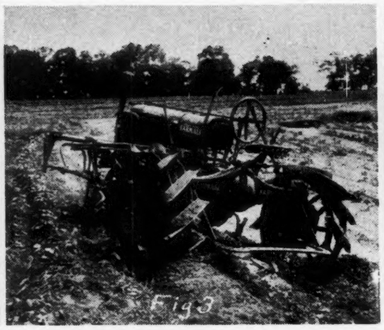
It was found that the entire surfaces of all plows studied could be described by arcs of circles moving along and rotating on or directly above the line of travel of the tip of the wing. Some plows required two arcs, others required only one to describe the surface. A mechanism was devised for measuring the angle (ϕ) of the plane of the arc and the line of travel, the angle (θ) produced by the elevation of the free end of the chord of the arc, and (t) the distance of travel. The entire surface was described by parametric equations giving the relationships of the angles ϕ, θ, and t, which are expressed by the general formula θ or $\phi = ce^{bt}$.

It was found that the perpendicular differential sections of the pulverization area for all plows studied could be expressed by the type formula $z = ae^{bx}$. The relationship between the shape of the perpendicular differential sections and the method of describing the plow surfaces by moving the area is explained.

The turning of the furrow slice was found to be accomplished by spiral easement or uniform-pressure curves, similar in principle to those employed in highway and railway engineering. Projections of the path of soil particles were found to be sections of logarithmic or equiangular spirals of the general formula $R = ae^{m\omega}$, where R is the radius, ω the angle through which the radius has turned, and a and m constants. The banking or superelevation of this spiral was found to be proportional to the turning; that is, $\theta = \rho e^{kt}$, where ρ and k are constants and the other symbols have the significance previously explained.

The mechanical principles of pulverization, turning, and inversion by uniform pressure surfaces whose sections have the above formulas are suggested as a basis for design of plows. Variation of the constants in the formulas would enable the principles to be adopted to different soil conditions and speeds of plowing. A number of variations of the application of the principles are pointed out from a study of different plows.





These pictures show the cultivation of cotton on the lower side of the terrace ridge. Fig 2. (Left) Note how the front wheels are at an angle to hold the tractor on the ridge. Fig 3. (Center) This shows the creep downward of the rear wheels until they have completely torn out the cotton row. Fig 4. (Right) This shows the outfit on the inside curve of the terrace; the tractor is working quite well

The Operation of Power Machinery on Terraced Land[1]

By R. W. Baird[2]

AT THE federal soil erosion experiment station at Tyler, Texas, the principal cultivated crops are cotton, corn, and cow peas. Since the spring of 1930 these crops have been grown on terraced land, and all the work has been done with tractor-operated machinery. Considerable trouble has been experienced with the planting and cultivating equipment used, because it was designed primarily for use on comparatively level land with straight rows. At the Tyler station the land slopes of the cultivated terraced fields are from 4 to 10 per cent, and on most of this land the rows are parallel to the terraces. The soil varies from a tight clay or sandy clay loam, occurring usually on the steeper slopes, to a very fine loose sandy loam on the gentler slopes.

This paper will be limited to those questions involved in farming parallel to terraces, as the crossing of terraces does not seem to be practical on loose soils and steep slopes.

The problem of designing large farm machines for use on terraced land is comparatively new, because Mangum terraces were first extensively used in a territory where much of the field work was and still is done with one-mule implements.

For terraces to be effective and still not be prohibitive in cost, the terrace ridge should be from 15 to 18 in above the terrace channel, and of a width such as can be crossed satisfactorily. At first thought it might seem that the terrace ridge might merely be widened until satisfactory operation is obtained. One objection to this is the increased cost of such terraces. On steep slopes there is another objection as illustrated in Fig 1. These two terraces are of the same width and of similar cross sections and represent the same amount of earth moved. However, the terrace on the 5 per cent slope has an effective height from the bottom of the channel to the top of the ridge of 18½ in while the one on the 10 per cent slope has an effective height of only 12 in. From this it will be seen that the construction of terraces of equal effective heights requires the moving of more earth on steep slopes than on more gentle slopes. The cost of building very wide terraces on steep slopes would be prohibitive; therefore, the practical width of terraces on steep slopes is limited. The cross section of the terrace shown is typical of the terraces at the Tyler station on land slopes of about 7 per cent on which tractor machinery has been used.

Plowing and other seedbed preparations on terraced land are not especially troublesome. The field is plowed in lands backfurrowing on the terrace ridge. This makes a considerable amount of short turning in finishing a land, because the distance between terraces varies as the slope of the land changes. There is also some difficulty in obtaining clean covering on the side of the terrace ridge. However, with a little care and labor reasonably satisfactory work can be done.

[1]Paper presented before a joint session of the Land Reclamation Division and the Power and Machinery Division at the 26th annual meeting of the American Society of Agricultural Engineers, at Ohio State University, Columbus, June 1932.

[2]Associate agricultural engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Jun. Mem. A.S.A.E.

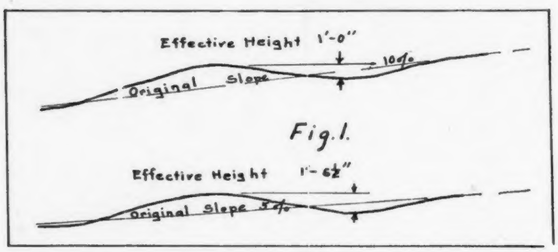


Fig 1. Cross sections of terraces on land with slopes of 5 per cent and 10 per cent, of the same width and similar cross sections but different effective heights

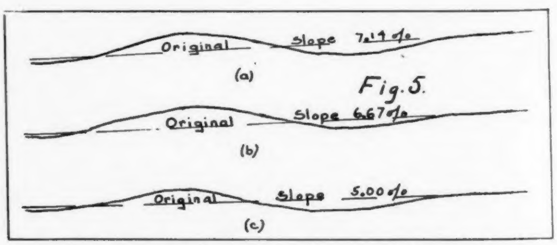


Fig 5. Cross sections of terraces at locations where the pictures of the tractor and cultivator in Figs 2, 3, and 4 were taken, indicated by (a), (b), and (c), respectively

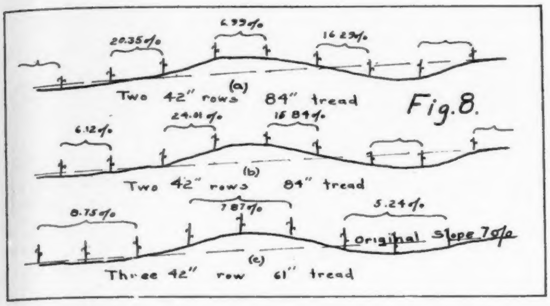


Fig 8. This sketch shows the slope of the tractor while planting and cultivating with different row arrangements and numbers of rows

In planting and cultivating, more serious difficulties are encountered. The common method of laying out rows is to run them parallel to the terraces, with short point rows to fill the wider places between terraces and with four or six rows on the terrace ridge.

At this station the rows are run parallel to the terrace above, with the point rows ending in the terrace channel. As there is usually some damage to crops in the terrace channel on account of standing water, it was thought that this method would lessen the damage done in turning.

With the two-row tractor planter set up according to the manufacturer's directions, the furrow openers were 20 in from the main planter wheels. Used this way, the machine could not be adjusted so as to avoid planting too deep when the two top rows were planted at the same trip. Also, in the terrace channel, with one planter wheel on the terrace and one on the upper side of the channel the furrow openers would not reach the ground. This trouble was greatly lessened by reversing the wheels and pawls, and putting the fertilizer distributor drive sprocket outside the wheels. This brought the planter wheels 9 in closer to the furrow openers and made it possible, on most terraces, to plant the two rows on top at the same trip. On curves and steep slopes, the covering press wheels, which are at a considerable distance behind the furrow openers, do not follow the furrow openers and hence do not cover well.

The troubles just described are also encountered with cultivators, and in addition it is difficult to follow the rows already laid out. Figs 2, 3, and 4 show the cultivation of cotton on the lower side of the terrace ridge. Notice the angle at which the tractor is held on the slope, how the front wheel must be held at an angle to offset the creeping of the tractor down the slope, and how in some cases the tractor wheels tear out the plants in the adjacent rows. Fig 5 shows the cross sections of the terraces at the points where these pictures were taken. Planting and cultivating the two rows on top of the terrace at the same trip is somewhat more satisfactory than cultivating the two rows on the side of the terrace at the same trip, as the angle at which the tractor works is reduced. Very little progress has been made in improving the operation of cultivators over terraces. Figs 6 and 7 show the work done by the cultivator. In Fig 6 the soil is sandy, and the creep and wheel slippage completely ruined the row for a considerable distance. In Fig 7 the soil is a gravelly clay well compacted, and the cultivator did fairly satisfactory work. The cross sections of the terraces where these pictures were taken are approximately the same.

Fig 8 shows the effect of different row arrangements and number of rows on the slope at which the tractor must operate in planting and cultivating the terraces. The terrace cross section used is a typical cross section on a 7 per cent slope.

In Fig 8 (a) the two rows on top the terrace are planted together and the maximum slope is 20 per cent. Planting the two rows on the side of the terrace together, as in Fig 8 (b), makes the maximum slope 24 per cent. The arrangement shown in (a) has been used this year and is more satisfactory. Figure 8 (c) shows what can be done to reduce the slope at which the tractor operates by using a wider machine. The maximum slope at which the tractor must operate is 8¾ per cent. The difference between working a tractor at 8¾ per cent slope and 24 per cent slope is enough to justify further study of methods of operating tractor machinery on terraces. The 3-row planter and cultivator have not been used at this station. A greater flexibility of the machine will of course be required with increased width.

Improvements could probably be made in the design of wheels and wheel equipment that would lessen the damage due to creeping and wheel slippage. No work has been done at Tyler on this phase of the problem.

In general, the additional requirements for the satisfactory operation of tractor machinery on terraces are (1) greater range of vertical adjustments that can be made by the operator from the tractor seat, (2) greater flexibility of the machine, (3) more positive steering control, (4) more compact units, and (5) greater care in selecting a width of machine to fit the terraces.

The greater range of adjustments could be obtained quite easily by changes in levers or cranks. More flexibility is necessary in order that the tools may fit more closely the cross-section of the terrace, and might be obtained by suitable gage wheels or by hinges in the machine that will allow vertical movement controlled by gage wheels. More positive steering might be obtained by a change in wheels and wheel equipment, and a design that permits less backlash when the steering gear becomes somewhat worn. For satisfactory operation on uneven slopes and crooked rows compactness is essential. Compactness might be obtained by placing the wheel and covering devices as close as possible to the other elements of the machine without interferring with their satisfactory operation.

These two views show the work done by the cultivator. In Fig 6. (Left) the soil is sandy, and the creep and wheel slippage completely ruined the row for a considerable distance. In Fig 7. (Right) the soil is a gravelly clay well compacted, and the cultivator did fairly satisfactory work

Artificial Light and Plant Growth[1]

By Dr. John M. Arthur[2]

IN CONSIDERING the commercial application of artificial light to plant production it is appropriate to discuss first some of the outstanding effects of various regions of the solar spectrum on living plants. Most of our green plants seem to grow well in sunlight, but it would be costly, if not impossible, to duplicate sunlight accurately in all of the many variations of quality, intensity, and length of day, using artificial light sources. Beyond this we cannot be sure that sunlight, as the plant receives it, is ideal for plant growth until we have considered the effects on plants of variations in quality, intensity and duration of light. The solar spectrum is indicated in Fig 1. The numbers represent wave lengths in millimicrons. The letters show the position of the Fraunhofer lines, while the color regions with their respective wave length ranges are shown below the spectrum.

In the case of Vitamin D production, and in the cure of rickets in the animal, a small amount of energy at the extreme ultra-violet limit for sunlight is very effective. The maximum of this effect is found between the limit of transmission of window glass and the solar limit indicated in Fig 1. It is unfortunate that this idea has been quite generally carried over to plant production and many persons believe that a little light from some mysterious ultra-violet lamp will be quite effective in forcing a pet geranium out of the doldrums of low intensity winter sunlight. The narrow band of energy near the limit for sunlight is of no known advantage in increasing the dry weight of plant tissue produced, or in hastening the time or increasing the amount of flowering. It has an effect in increasing the depth of pigmentation in the case of certain red pigments which normally form only in light, such as the red pigment in the stems of buckwheat, in the leaves of certain varieties of red lettuce, in the peels of apples and other fruit. These pigments are also formed to a certain extent in the blue-violet region of the visible spectrum, but they are definitely increased by ultra-violet. The characteristic red color can be developed in poorly colored McIntosh apples after picking by exposing them to a mercury vapor lamp in Uviol or Pyrex glass for a period of 48 to 72 h during the first three weeks in September. In this work it is necessary to remove all rays of wave length shorter than 290 mμ (millimicrons) on account of the lethal effect on the epidermal cells. Production of pigment is a function of the living cells of the apple peel. It is important that the fruit be picked early and treated at once as the cells of the peel die after a few weeks in storage. Color production is greatly aided by a low temperature of about 15 deg C (degrees Centigrade). Window glass filters greatly retard the development of this pigment. The region of maximum effectiveness in red pigment production of apples is, therefore, in the extreme ultra-violet region of sunlight and closely parallels the region of maximum antirachitic effect in animals.

Ultra-violet beyond the limit for sunlight, that is, of wave length shorter than 290 mμ, is very injurious to plants. In the case of a tomato leaf, for example, the injured areas take on a characteristic varnished appearance. An exposure of 30 sec to a mercury vapor lamp in quartz is sufficient to produce marked injury to young tomato plants. As more of the extreme ultra-violet is removed from this light source by means of appropriate filters, the time for producing the same injury increases rapidly until it requires more than 50 h in one continuous exposure to produce any injury through a filter transmitting to wave length 285 mμ. Injury at this wave length appears only when the plant is kept in darkness for a few days previous to the exposure. While it is believed that there is no possibility of injury from the extreme ultra-violet region of sunlight, it should be pointed out that whenever the natural range of color radiation is overstepped by a very narrow margin, either in intensity or wave length, injury results. This is important in choosing an artificial light source for growing plants as many arc lamps and other sources exceed this natural range for sunlight in the ultra-violet region.

At the opposite end of the solar spectrum is the infra-red region which includes slightly more than 50 per cent of the total energy of sunlight. This region is of no known

[1]Paper presented at a session of the Rural Electric Division of the American Society of Agricultural Engineers during the 26th annual meeting of the Society held at Ohio State University, Columbus, in June 1932. A contribution of the Committee on the Productive Uses of Light in Agriculture.

[2]Boyce Thompson Institute.

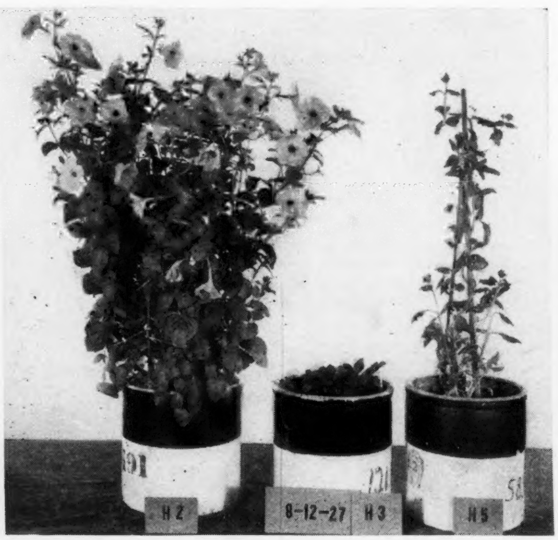


Fig 2. Petunia plants. H2, at left, grown with the complete solar spectrum. H3, in middle, grown under a blue glass which transmits no red. H5, at right, grown under a glass which transmits red-green region but no blue

Fig 3. Buckwheat seedlings. Those at left grown with sunlight in a greenhouse; those in middle with 30-lpw lamp; those at right with 10-lpw lamp at the same illumination value

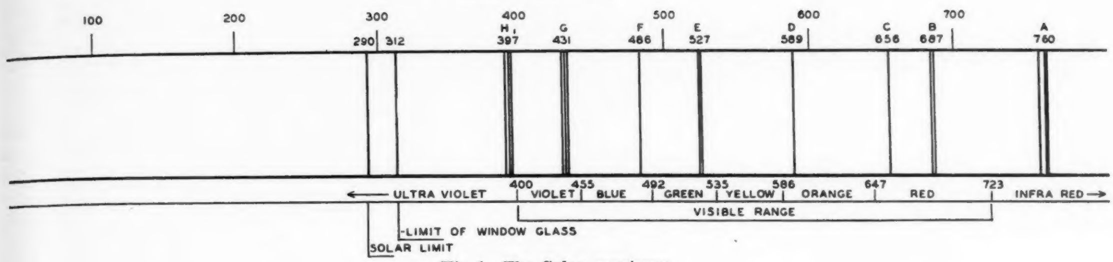


Fig 1. The Solar spectrum

significance to plants, except in so far as it serves to increase the temperature of the plant, air, and soil. Photosynthesis, the fundamental process of green plant cells whereby the energy of sunlight is fixed in carbon compounds such as starch, cellulose, and wood, does not take place in the infra-red region. The green pigment chlorophyll is not produced when plants are exposed only to infra-red, so that seedlings grown under this region of sunlight appear identical with those grown in darkness. In the case of two pots of buckwheat seedings—one grown in darkness and the other grown with only the infra-red region of sunlight—the average weight per plant from the two lots was the same, and they were identical in appearance as neither lot produced chlorophyll. The plants grew only at the expense of the food stored originally in the seed.

Although the infra-red of sunlight is not necessary for plant production it is not known to be injurious to green leaves, as these have an effective method of eliminating excess energy by the evaporation of water. This provision always serves to keep the green leaf at a temperature which is approximately the same as air temperature. Fruits such as the apple in the later stages of development produce an impervious covering or peel which differs from green leaves in that it does not transmit water and therefore does not have the ability to lose excess energy by evaporation. McIntosh apples can be burned severely by the infra-red only from a 500-watt incandescent lamp at a distance of 30 in, even though they are held continuously at a temperature slightly above freezing (2 deg C). The internal temperature of the apple is increased about 20 deg above that of the surrounding air. The injury produced by this region is a wrinkling and browning of the tissue on the side exposed to the lamp, and resembles the injury produced on fruits and vegetables by sunlight which is commonly known as "sun scald." Fruits are normally protected from exposure to light by the green leaves, while if these are removed by insects or other causes, injury results.

Fig 4. Tomato plants grown on various day lengths of artificial light, except control at right which was grown in a greenhouse

Only the visible region and the near ultra-violet are used in the process of photosynthesis. Since there is approximately 45 per cent of the total energy of sunlight in the visible region this is the region of first importance in the process of photosynthesis. Of the visible region of sunlight both the red and blue ends of the spectrum are necessary to plants. The red-yellow region is especially desirable in furnishing considerable energy for the process, yet plants grown under this region alone have abnormally long thin stems and thin leaves resembling plants grown in a greatly reduced light intensity. The effect of different regions of the spectrum on the growth of petunia plants is shown in Fig 2. The plant at the left was grown under a glass transmitting the complete spectrum, while that at the right was grown under a glass which transmits the red-green region but no blue. The small plant in the middle was grown under a blue glass which transmits no red. All plants are the same age and were grown at the same air temperature. The blue-green region is essential in producing normal stems and good chlorophyll development and prevents excessive elongation. Plants will not grow to normal height under the blue-green region alone at an energy level of approximately 10 per cent of the total energy of summer sunlight. It is not known whether a normal plant can be grown under this region alone if an energy value equal to that of summer sunlight were supplied. On the other hand, it is reasonably well established that normal plants, as they appear in nature, cannot be grown under the red-green region of sunlight even at a high-energy level; the balancing effect of the blue is necessary.

In recent experiments the growth of buckwheat seedlings, as measured by dry weight production, was compared using 500-watt incandescent lamps at 10, 20, and 30 lpw (lumens per watt) efficiency, respectively. The dry weight production followed closely the foot-candle intensity as measured by a Weston photronic cell with a maximum sensitivity in the yellow region and was not related to the total energy output of the lamps as measured by thermopiles. The record of a single experiment will serve to illustrate this point. Two 500-watt incandescent filament lamps were mounted in a basement room in which air temperature and humidity were held constant by standard air-conditioning machinery. The room temperature averaged 25.5 deg C. The filament of one lamp was wound by the manufacturer to burn at an efficiency of 10 lpw, the other at 30 lpw. The labeled voltage of each lamp was 120 and the operating voltage 118 to 120. The lamps were fitted with "Factrolite" aluminum reflectors. Four 8-in pots of buckwheat seedlings were placed under each lamp, and the light intensity on the soil was adjusted to the same value by raising or lowering the lamps. A Weston photronic cell was used to make this adjustment accurately, after which the foot-candle intensity was read by means of a Macbeth illuminometer. The reading was 205 ft-c (foot candles). The total energy value at the soil level under each lamp was determined by means of three different types of thermopiles and the readings averaged. The total energy under the 30-lpw lamp was found to

be only 49 per cent of that under the 10-lpw lamp. The distance of the tip of the 10-lpw lamp above the soil level was 33.5 in, while that of the 30-lpw lamp was 57.5 in. The plants were exposed continuously to the two lamps for 12 days, after which they were cut off at the soil level and the average green and dry weight determined. The results were as follows:

	Number of plants	Average green weight in grams per plant	Average dry weight in grams per plant
1. Weight of buckwheat seedlings 9 days old at start of experiment, March 5, 1932	77 69	0.468 0.490	0.0276 0.0285
2. Weight of seedlings grown in greenhouse 12 days starting March 5, 1932	69 59	2.850 2.840	0.163 0.162
3. Weight of seedlings grown under 10-lpw lamp for 12 days starting March 5, 1932	60 58	2.580 2.520	0.104 0.099
4. Weight after grown under 30-lpw lamp for 12 days starting March 5, 1932	56 62	2.530 2.550	0.089 0.092

It will be noted from the above results that both the green and dry weights of plant tissue produced are approximately the same whether a high or low efficiency lamp is used, if the lamps are placed at a sufficient distance to give the same foot-candle illumination. Under the conditions of this experiment a low efficiency lamp (10 lpw) produced as much plant tissue at 33.5 in from the soil as a high efficiency lamp (30 lpw) at 57.5 in. Neither of these lamps burning continuously was as effective in producing plant tissue as sunlight in a greenhouse during the same period (March 5 to 17, 1932). The natural length of day during this period was approximately 12 h. The period included only three cloudy days, all others being well above the average for the month. Photographs of seedlings from each of the three conditions are shown in Fig 3. Those at the left were grown in the greenhouse, those in the middle under the 30-lpw lamp, and those at the right under the 10-lpw lamp. The seedlings grown under the lamps are much taller and have weak stems as compared with those grown in the greenhouse. This is mainly the effect of the low intensity (205 ft-c) under the lamps as compared with sunlight which exceeded 4600 ft-c each day, except two, according to the records of the New York Meteorological Observatory. The 10-lpw lamp burned continuously during the 12-day period with no measurable decrease in light output. The 30-lpw lamp was replaced at least once in each 24-h period. The growth of buckwheat seedlings under a 10 and 20-lpw lamp was compared under conditions similar to the above experiment. The 20-lpw lamp which is usually sold for industrial lighting has normally a life of 1000 h. It was found that when suspended similarly at 42.5 in from the soil level, it produced the same foot-candle illumination and approximately the same dry weight of plant tissue as the 10 and 30-lpw lamps in the experiment already described.

These results indicate that the dry weight of plant tissue produced is closely related to the output of a lamp in the visible region and increases with increasing efficiency of the light source due to the shifting of the maximum of energy output from the infra-red toward the visible. The infra-red output of a lamp, while of no particular use to the green plant leaves, is apparently not injurious as long as it does not result in undue heating of the surrounding air. Considering the increased growth of plants with increasing efficiency of light sources, it is very important to choose a source which is as efficient as is consistent with replacement cost of lamps, cost of current, and with practical operation. In the case of the incandescent lamp, engineers calculate this to mean burning the lamps at approximately 105 per cent of their labeled voltage, using current at 4c per kilowatt. Arc lamps are in general more efficient light sources for plant growth, but on account of the difficulty of maintenance have so far not been widely used. Incandescent lamps have too little of the blue-green region as compared with the preponderance of red and infra-red to be ideal light sources for growing plants, yet they are of real service as a practical source for supplementing low-intensity winter sunlight for 3 to 6 h each night. Greater application of artificial light will be made as more efficient lamps are developed. Experiments have shown that many plants produce the greatest dry weight increase on an 18-h day, 12 h of which is natural sunlight. While many plants will withstand continuous illumination successfully, others are slightly injured by it, and still others, like the tomato and geranium, will not withstand continuous illumination, requiring a period of approximately 6 h rest in darkness in each 24-h period. A series of tomato plants grown with artificial light only is shown in Fig 4. The length of day, or time of exposure to the light in each 24-h period, varied from 5 to 24 h, or continuous illumination. The control plant at the right was grown in the greenhouse during the same period, from February 28 to May 4, 1925. The greatest height and dry weight increase was produced on a 17-h day. Both the 19 and 12-h day plants weighed less than the 17-h day plant, and the 24-h day plants did not survive this continuous light condition. The illumination at the soil level was approximately 800 ft-c, the light source being 25 1500-w 120-v lamps burning on 105-v current used in conjunction with a water and glass filter. Other tomato plants grown in a greenhouse during the same period received 6 h of artificial light each night from a Gantry crane carrying 48 1500-w lamps. The illumination in the latter case was approximately the same, but the weight of tissue produced was much greater than that grown under artificial light only. Daylight, even though of low intensity, is normally much greater than the artificial light which can be added in a practical way, and in addition it has a definite balancing effect on the growth of plants which is lacking in most artificial light sources.

It should be pointed out that the foregoing energy considerations apply to growth or dry weight increase of plants and not to flowering. Intensities as low as 10 ft-c applied for 6 h each night are often sufficient to produce flowering on a long-day plant or inhibit flowering on a

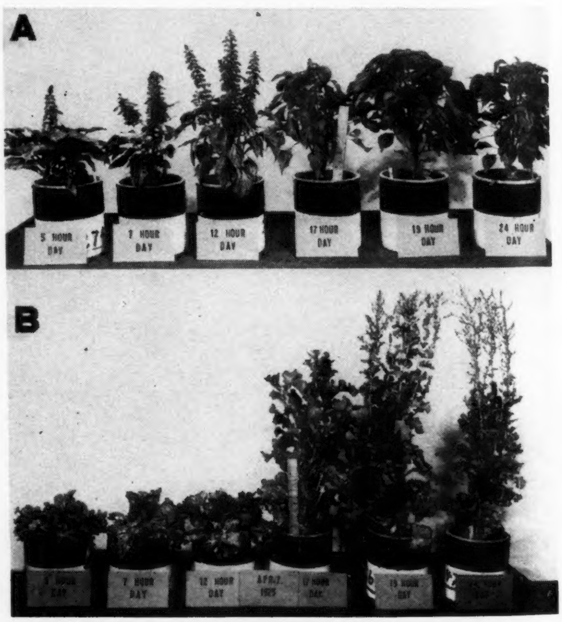


Fig 5. (A) Salvia. This plant flowers on short days. (B) Lettuce. A plant which flowers only on long days

short-day plant, while the building up of the body or dry weight of the plant requires much more energy. In Fig 5(A) is shown a series of salvia plants grown on 5, 7, 12, 17, 19, and 24-h days using only artificial light. This plant flowers on all day lengths up to 15 h and is typical of fall-blooming plants which in nature are brought into flower by the shortening of the day. Occasionally a single terminal flower will appear on a 17-h day as shown in the picture. Other short-day plants are certain varieties of dahlia, ragweed, cosmos, and chrysanthemum. Long-day plants such as lettuce and radish, which normally flower on the long days of summer, flower only on long days of artificial light. In Fig 5(B) is shown a series of lettuce plants grown with artificial light only on 15, 17, 19, and 24-h days. Not all plants are affected as to flowering by length of day. Buckwheat plants flower on all lengths of day from 5 to 24 h. Many plants commonly grown in greenhouses, such as snapdragon, rose, sweet pea, and phlox can be brought into flower rapidly on day lengths of 15 to 18 h, using artificial light at intensities of 800 to 1000 ft-c as a supplement to sunlight. This supplementary lighting can be done, to best advantage, after midnight when the demand for electrical power is lowest. Public service companies will usually grant special rates to consumers during such times of off-peak loads.

(AUTHOR'S NOTE: The author hereby gratefully acknowledges his indebtedness to L. C. Porter and other members of the Nela Park Laboratory of the General Electric Company for their assistance in furnishing lamps of different efficiency rating and for supplying data on the relation between efficiency, cost of current, and cost of lamps.)

A Study of Isolated Electric Plant Costs

By A. G. Tyler[1]

A CONSTANT repetition of the question of lighting plant costs induced us to try to find an unbiased answer to the problem. So many factors enter an investigation of this kind that it becomes difficult to know what to include and what to leave out. The most difficult part was to get a representative cross-section of conditions as they actually exist.

In order to cover as large a field as possible the county agents were asked to send in the names of half a dozen or so users of isolated plants in their respective counties. Most of the agents responded, and a questionnaire was sent to each of the addresses submitted. As was to be expected, only a small number (about 20 per cent in this case) of the questionnaires ever came back. Of those that did come back only about 20 per cent were of much use. The information obtained from mailed questionnaires was highly unsatisfactory.

For some years past the practice has been to get the information from college students who come from homes where lighting plants are used. Many of the answers are, of course, only estimates and their influence on the conclusions must not be overlooked. Operating costs and the length of time the various lights are on are the questions which seem to be the hardest to answer. In no case have doubtful or improbable answers been used.

The following information is what was left after culling perhaps three hundred replies. In general no questionnaire has been included unless at least half the answers seemed reasonable.

States represented (10): Wisconsin, 6; New York, 3; Michigan, 5; Pennsylvania, 1; Kentucky, 1; Vermont, 1; Texas, 1; Minnesota, 55; Nebraska, 1; Iowa, 1; total, 75.

Make of plant (14): Acorn, 1; Delco, 45; Everlite, 1; Fairbanks-Morse, 1; Fuller and Johnson, 1; Kohler, 1; Lally, 1; Rohaco, 2; Rumely, 1; Universal, 1; Warner Automatic, 1; Westinghouse, 11; Western Electric, 3; Willys Light, 3; total, 73.

Size of generator: 600-w, 2; 640-w, 1; 750-w, 22; 800-w, 1; 850-w, 4; 1000-w, 3; 1200-w, 1; 1250-w, 2; 1500-w, 6; total, 42; average size, 910-w.

Capacity of battery (ampere-hours): 80 ah, 13; 100 ah, 1; 116 ah, 1; 120 ah, 2; 125 ah, 1; 140 ah, 2; 160 ah, 23; 170 ah, 1; 180 ah, 1; 188 ah, 1; 210 ah, 2; 225 ah, 1; 267 ah, 1; 275 ah, 1; 320 ah, 1; total, 52; average, 147.

Fuel used: Kerosene, 49; gasoline, 21; natural gas, 2; total, 72.

Hours used per week: From 2 to 60. Average of 67 plants, 13.29 h. Leaving out the plants that were used more than 30 h per week (6) as probably doing some commercial work, the average for the remaining 61 plants was 10.42 h. The average for plants used 20 h per week or less (55) was 9.03 h. The average for plants used 10 h per week or less (40) was 5.95 h.

The plants on which figures are available (67) were used as follows:

100 per cent use plant 2 h or more per week
80 per cent use plant 5 h or more per week
40 per cent use plant 10 h or more per week
25 per cent use plant 20 h or more per week
8.9 per cent use plant 30 h or more per week
4.5 per cent use plant 40 h or more per week
4.5 per cent use plant 50 h or more per week

Of the plants used 30 h or more per week, three were used for charging automobile batteries, two in large dairies, and one for belt work in a machine shop. All six were also used for house lighting.

Cost of plant and battery. The cost ranged from \$100.00 to \$1,000.00 per unit. The average cost of 65 plants was \$500.80. If the two \$1000.00 plants are omitted, the average cost of 63 is \$485.01.

Repairs (yearly). The range is from zero to \$25.00. The average for 57 plants is \$3.98. Of those that admit having any expense (38) the average is \$5.97.

Plant installed. In tool shed, 2; basement, 54; basement of milk house, 1; pit in engine room, 1; milk house, 5; barn, 3; summer kitchen, 1; shop, 1; outhouse, 1; special shed, 4; total, 73.

Age of battery. (No battery less than a year old considered.) Average of 71, 4.59 years.

Monthly cost of fuel and oil. The cost of 56 plants ranged from \$0.25 (natural gas) to \$20.00 (gasoline), the average being \$3.086. Deducting those with a monthly cost of \$8.00 or more (3), the average of the remaining 53 is \$2.506.

One light on. Of those answering only 28 said that they used one light only for any appreciable time. The average of the 28 was 3.48 h. This information may be of value as it affects the use of the automatic plants.

Lights on each day.

Kitchen—from 1 to 6 h; average of 60 plants, 3.41 h

Dining room—from ½ to 6 h; average of 53 plants, 2.55 h

Living room—from ½ to 6 h; average of 54 plants, 2.75 h

Bedroom—from 10 min to 10 h; average of 57 plants, 1.63 h

Average in bedrooms not using night lights (53), 1.05 h

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Light on in kitchen, 14.2 per cent of time
Light on in dining room, 10.3 per cent of time
Light on in living room, 11.4 per cent of time
Light on in bedroom, 6.8 per cent of time
Light on in bedroom (neglecting night lights), 4.4 per cent of time.

Appliances. Of the 72 that had appliances the number and per cent were as follows: 42 irons, 58 per cent; 48 washing machines, 66.5 per cent; 4 toasters, 5.5 per cent; 39 pumps (in 36 places), 18.5 per cent; 30 separators, 41.5 per cent; 18 vacuum cleaners, 25 per cent; 1 sewing machine, 1.4 per cent; 20 power stands, 27.8 per cent; 14 fans, 19.4 per cent; 7 milking machines, 9.7 per cent.

Several other uses for electric current have been given but only those listed on the original questionnaire have been considered.

Operating Cost[2]. The average plant costs $485.00, of which one-third is assumed to be for the battery and two-thirds for the engine and generator. If the plant has a life of ten years and the battery five years, the yearly cost will be about as follows:

Engine and generator, 10 per cent of $323.20	$32.32
Battery, 20 per cent of $161.60	32.32
Interest on investment (on one-half of first cost)	14.55
Maintenance (repairs)	3.98
Operating costs ($2.61 per month)	31.32
Taxes, overhead, etc. (not considered)	0.00
	$114.49
Monthly cost	$9.54

The information pertaining to the length of life of the generating plant and the battery is perhaps the most questionable of any listed. Lighting plants are practically never junked. The battery may be junked, but more often it is traded in toward a new battery. There are a number of instances where the generating unit is more than fifteen years old, and several where the same battery has been in use up to ten years.

One of the plants in the University laboratory has been there fifteen years. It has been used relatively little and has had expert care so that now it is practically as good as new. The original 80-ah battery was in use nine years and was changed only because the company that owns the plant thought that a larger battery would be more representative. Another plant and battery (80-ah) has been in use in the laboratory twelve years and is still going strong.

The average size of generator (42) is 910 w. The average time plant is running (67) is 13.29 h per week, or 57.59 h per month. Simple calculation gives 52,407 wh, or 52.407 kwh per month. The average cost per kilowatt-hour is then 18.3 c.

It is possible that the figures or the conclusions based on them may be objected to for one reason or another. That attitude would be perfectly proper and to be expected. It is impossible to entirely eliminate the personal element in the collection and compilation of data such as these and that fact must not be overlooked when evaluating the conclusions.

Assuming that the energy consumption is the same as with the isolated plant, namely 52.07 kwh per month, the cost of high-line service at $4.50, minimum rate, 7 c for the first 70 kwh, and 3 c for all additional, will be $4.50 plus (52.07 x .07, or $3.65), a total of $8.15. The cost per kilowatt-hour will be 15.6 c.

To visualize the effect of quantity consumption on the unit price, assume for instance that the monthly energy consumption is 152 kwh, instead of 52 kwh. The monthly bill will be $4.50 plus (70 x .07) plus (82 x .03), or $11.86. The cost per kilowatt-hour will be 7.8 c as compared to 15.6 c, just half as much in this case.

The same effect will obtain with the isolated plant, but to a lesser degree because the operating and maintenance charges are directly proportional to the use of the plant.

[2]This investigation was carried on from 1923 to 1928, when costs were considerably different than at present.

A Light Trap with Suction Fan[1]

By W. B. Herms[2]

FOR MANY YEARS the inhabitants along the shores of Clear Lake, California, together with vacationists, have been greatly annoyed during the summer months by huge swarms of non-biting gnats which drift in from the lake about dusk on quiet evenings. These gnats, scientifically known as Chaoborus lacustris, originate from larvae which are quite transparent, known also as phantom larvae, and occur rather far out from shore where the water is fairly deep. The breeding habits of these insects render control in their immature stages practically impossible.

The winged gnats (adults)—both male and female—are strongly attracted to light and come to the shores of the lake in veritable clouds. The usual form of light traps resulted in capturing only a small percentage of these insects. Because of their very light weight it was found that they could be easily sucked into a bag as soon as they began whirling about the lamp. This led to the construction of a trap provided with a suction fan.

The trap which was finally devised consisted essentially of (1) a 100- to 300-w lamp to attract the insects; (2) a tin or sheet iron sleeve from 12 to 15 in in diameter and 18 and 24 in long, held in place by three ¼-in rods suspended from the reflector top; (3) a small ventilating fan with motor fastened inside the sleeve; (4) a bag of black muslin or other thin material about 3 ft deep to catch the gnats drawn down by the suction fan, and (5) a windshield with vane to prevent breezes from pushing the gnats away from the trap. These traps were suspended at an elevation of from 8 to 12 ft along the shore of the lake and near cottages and resorts.

During the first summer of our investigations a total of 156 lb of gnats was captured, as many as eleven pounds for one trap in two hours. Since there are approximately 1½ to 2 millions of gnats per pound, some idea of the efficiency of this trap may be gained. A matter of further interest is that these insects come to the shore before laying eggs, hence are captured before their return to the water for oviposition.

The immediate result of this trapping was most gratifying, and it is believed that an extensive use of such traps would eventually result in a material reduction of the species. For larger insects such as moths a suction fan device would probably need considerable modification because of the power needed to draw them in and also because of the clogging up of the fan.

[1]Abstract of a paper presented at a session of the Rural Electric Division of the American Society of Agricultural Engineers during the 26th annual meeting of the Society held at Ohio State University, Columbus, June 1932. A contribution of the Committee on the Productive Uses of Light in Agriculture.

[2]University of California.

The Elastic Drawbar

By Wm. Vutz[1]

SHOCKS are always more or less detrimental to machinery if provisions are not made to absorb them. Springs are the mediums most commonly used for this purpose. Pneumatic tires, frictional and hydraulic vibration dampers are all common to the present-day automobile. Their principles, and their effect on the life of engine and body, are well understood.

On trucks designed for occasional or constant use in connection with truck trailers, experience has proved that in many cases the originally installed drawbar spring was not nearly of sufficient capacity to protect the frame from undue strains. This has led to a number of shock absorber designs. Some of the devices described in this paper were designed primarily for trucks and have proven their value.

For many tractors of the industrial type, load conditions are much like those of truck-trailer service. These tractors are generally rubber-tired and capable of speeds from 10 to 20 mph. The frequency of starting and stopping is perhaps much greater than with trucks. As a rule only the heaviest of these tractors are equipped by the manufacturer with drawbar springs.

Elastic drawbars have not been used on farm tractors because of first cost, because the friction clutch is thought to provide a sufficiently smooth starting, and because the drivewheels are depended on to slip under an overload. There are on the market already lighter farm tractors capable of speeds from 5 to 7 mph. The tendency of the future will be to further increase the speed for return trips and light hauls.

The rapidly increasing application of power take-off drives to tractor-drawn machinery will certainly bring about better practice in hitching than is common today. Drawbar holes range anywhere from ¾ to 1¼ in in diameter. The drawbar, by reason of its design, may be free to move ½ to 1 in forward or backward. Clevices may allow an up and down play of ½ to 1 in. In operation this causes a jerky motion of the drawn machine and excessive vibration in the telescroping members and universal joints of the power take-off. Rigid or very tight hitching is impossible with a drawn vehicle of any appreciable weight.

Some manufacturers of the more costly types of tractor-drawn machines with relatively elastic frames, such as combines, try to prevent damaging shocks to their machines by incorporating springs into the tractor hitch. This is done in recognition of the fact that the friction clutch in a tractor will allow a smooth pick-up of the load only if properly handled, and that there is no way to modify the many shocks occurring while working under load, as in travelling through washouts or shallow ditches. A shock-modifying device should be an integral part of the tractor, to protect it as well as the drawn machine.

In the cases of trucks operated with trailers, or of corn harvesters, grain combines, or threshing machines drawn by tractor, shocks are mostly absorbed by certain members of the main frame. Abuse may often stress these frames beyond their elastic limit.

Let us consider a 3-wheel grain combine travelling at 3 mph with a total weight of 6800 lb, of which 5200 lb fall upon the two main wheels and 1600 lb on the one front wheel, requiring on level ground a pull of 1600 lb. Going through a shallow ditch or a washout it may encounter a grade of 1 to 5. When the main wheels hit this incline, this gives an additional load of 1040 lb on the tractor drawbar. Depending upon the suddenness of the shock and the amount of play in the hitch, the force transmitted at the instant of impact might actually be a multiple of this. If only 75 ft-lb of energy are transmitted from tractor to combine before the governor can react on the increased load, and if hitch and combine frame are able to deflect ½ in elastically under this impact of 75 ft-lb, it means that the force actually runs up to 3600 lb above the pull exerted by the tractor at the instant of impact. If we had a tractor equipped with a shock absorber giving an elastic travel of 1¾ in in this case the impact load would increase smoothly to a maximum of 1030 lb. Supposing the tractor to be equipped with drivewheels 42 in in diameter and to have a total reduction of 1 to 46, the shock absorber allows almost a 5-deg turn of the wheel or about a two-thirds revolution of the crankshaft.

A tractor that has an elastic drawbar can easily be equipped with an overload clutch release[2]. For plowing in stone-free fields at a continuous load, a means of locking the shock absorber might be desirable.

Summarized, the requirements for a shock absorber for use on agricultural or industrial tractors would be somewhat like this:

1. It should transmit smoothly any increase or decrease in load.

2. The reaction during recoil should be just enough to bring the drawn machine back into its right relation to the traction machine. This action should be without jerks or jolts, especially on faster travelling machines.

[1]Designer, J. I. Case Co. Assoc. Mem. A.S.A.E.

[2]"The Combination Cushion Spring and Clutch Release Hitch," by E. G. McKibben, AGRICULTURAL ENGINEERING, Vol. 12, No. 3 (March 1931), and "A Study of Tractor Stop Hitches," by Arthur W. Clyde, AGRICULTURAL ENGINEERING, Vol. 13, No. 3 (March 1932).

This Case general-purpose tractor is shown in its application, on an Illinois farm, to the cultivation of gladiolus and cabbages. It does the work better than horse equipment, the owner says, and at less cost

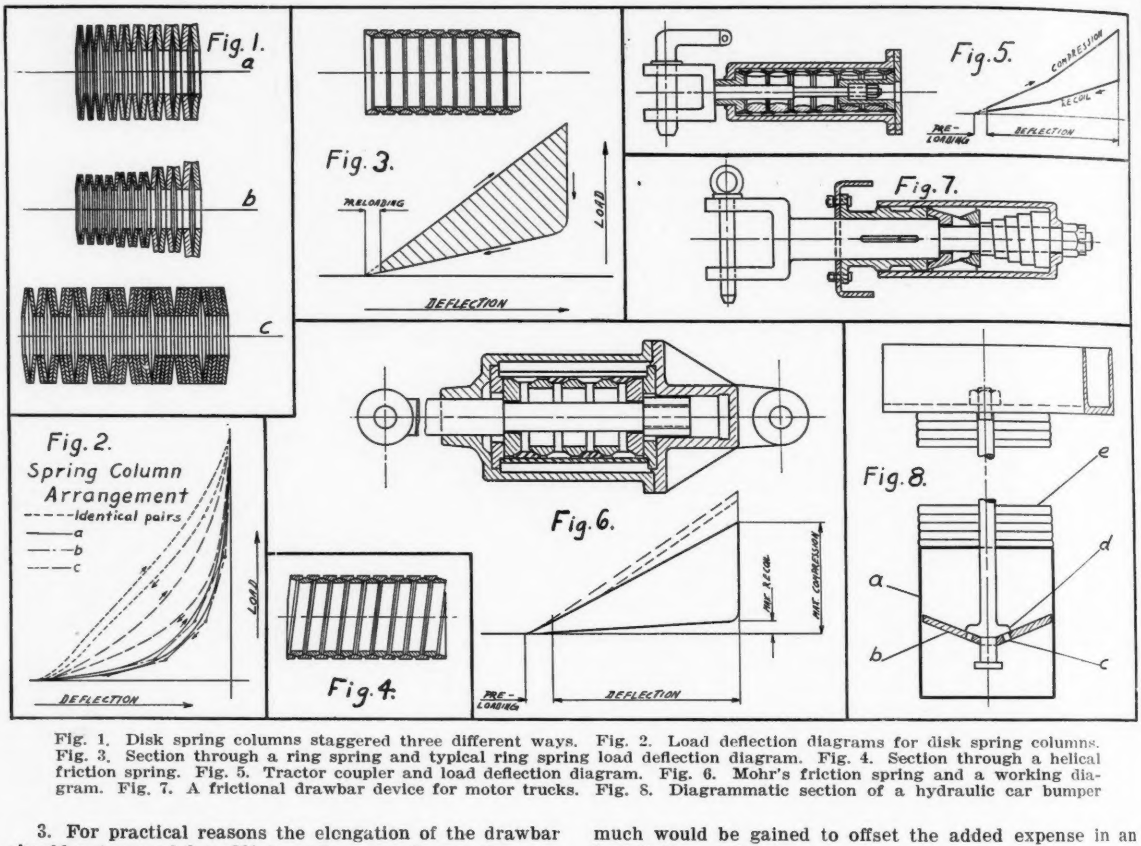

Fig. 1. Disk spring columns staggered three different ways. Fig. 2. Load deflection diagrams for disk spring columns. Fig. 3. Section through a ring spring and typical ring spring load deflection diagram. Fig. 4. Section through a helical friction spring. Fig. 5. Tractor coupler and load deflection diagram. Fig. 6. Mohr's friction spring and a working diagram. Fig. 7. A frictional drawbar device for motor trucks. Fig. 8. Diagrammatic section of a hydraulic car bumper

3. For practical reasons the elongation of the drawbar should not exceed 2 to 2½ in under normal operation condition.

4. For agricultural tractors a means of locking the attachment for use under constant loads, and means for connection to a clutch release, are desirable.

5. Low first cost and a minimum of attention during service.

SPRINGS

All shock absorbers designed so far rely, partly at least, on the elasticity of some material, either directly as a means to store energy, or indirectly as a means to bring the two connected parts back to their normal working position after an increase or decrease in load is transmitted. In the latter case the undesirable energy of a shock is diffused in some way, usually by transforming it into heat, as in frictional devices, or by accelerating a mass, as is done in hydraulic shock absorbers.

Helical Torsion Springs are the ones most commonly used so far, mainly due to their ease of installation and low initial cost. These springs possess practically no inner friction. The spring reaction during recoil is as great as the action under load. The load deflection curves are identical lines for compression and expansion. The fact that the spring reacts with an unchecked force introduces an undesirable condition in its use with faster travelling vehicles, inasmuch as every action of the spring is followed by a number of jolts back and forth before the spring finally comes to rest.

Leaf Springs of the elliptical or semi-elliptical type would give somewhat better results, as the friction between leaves acts as a damper of the rebound force. For a spring of given capacity the percentage of energy lost by friction changes inversely with the cross-sectional area of the leaves. As a spring designed for this purpose would hardly show a friction loss of more than 10 to 15 per cent, not much would be gained to offset the added expense in an installation of this type.

Disk Springs permit the transmission of great forces where relatively little room is available, although the deflection is generally small. To obtain a greater elastic spring travel, it is necessary to combine a number of disks to form a spring column. The advantages are that when one disk breaks, the action does not stop, as with a helical spring, and a single broken disk is less expensive to replace than a complete helical spring. If the spring is made of disks of the same diameter and thickness, the load-deflection curve resembles closely a straight line.

By staggering the diameter or thickness of the plates, or both, almost any desired spring action can be obtained. Fig. 1 shows three different arrangements. Fig. 2 gives the load deflection diagrams for these springs. The loss due to friction is around 10 per cent in arrangements like "a" and "b". With an arrangement as in "c," about 30 per cent of the energy is lost in friction between the layers during recoil. A suitable selection of disks, or the combination of a helical spring with a disk spring, gives a means for absorbing small shocks softly, and making the spring stiffer for heavier shocks.

Ring Springs are a type in which all parts are uniformly subjected to either tension or compression. As can be seen from Fig. 3, the spring is made of solid inner and outer rings, which contact with each other on their conical surfaces. Under an axial pressure the outer rings are subjected to tension and the inner rings to compression. The deformation of the rings is kept within elastic limits. It causes the inner rings to slip into the outer ones, giving a spring action in the direction of the longitudinal axis of the spring.

The relative motion of the rings is opposed by friction between their conical surfaces. In this way the force necessary to compress the spring is materially increased, while the recoil force is decreased. This property makes

the spring especially desirable for shock-absorbing work[3]. Fig. 3 gives a load-deflection diagram of such a spring.

As an advantage for this type of construction it can be cited that, in case one ring should break, the action of the spring is only slightly affected. The broken ring can easily be replaced without much expense. The number of rings changes the deflection of the spring, but does not have a bearing on the maximum load.

Generally the springs are mounted in dustproof housings and lubricated with a mixture of grease and graphite.

The spring in Fig. 4 is similar to the ring spring in construction and action. It consists of an inner helix of a cross-section similar to the one of the inner ring of the ring spring, the inner helix being screwed into an outer one corresponding to the outer ring of the ring spring. Both ends of both parts are firmly held in suitable end plates. Besides tensile and compression stresses in outer and inner coils the spring is subjected to some torsional stresses. By allowing a suitable amount of clearance between two coordinated friction surfaces, the spring can be made to react very softly to light loads.

In a similar device (Fig. 5) designed for tractor use, continuous outer rings contact on their inner conical surfaces with split inner rings. Under an axial load the outer rings are in tension and the inner rings are bent to a circle of a smaller diameter. At the same time they slip farther into the outer rings until the slot is closed. It is important that the circular shape of the inner rings be maintained under all loads. This is accomplished by properly diminishing the cross-section of the ring toward the slot. As will be noticed the last two inner rings are of heavier cross-section. This gives a relatively soft spring for light loads and gradually increasing resistance to heavier shocks. The working diagram in Fig. 5 clearly shows the point of inflection in the pressure curves at the instant when the heavier rings start to work. The maximum recoil force amounts to about 30 per cent of the maximum load.

Mohr's Friction Spring (Fig. 6) embodies a cylindrical wrapper spring, slotted in axial direction over its entire length, and enclosing slotted spring steel rings. These slotted rings inturn are held by solid inner pressure rings. Axial movement of the drawbar is transmitted by the solid inner rings pressing on and expanding the slotted intermediate rings, which in turn contact and expand the outer wrapper spring radially. The friction between the solid and the slotted rings and between the slotted rings and the wrapper spring, materially increases the resistance to a load, and in the same way decreases the recoil force. Designed for a maximum load of 6000 lb, the attachment will react with a force of 600 lb during recoil. The useful spring travel obtained from each spring element is approximately 13/32 in. A spring element is one slotted ring with its two adjacent conical surfaces of solid inner rings and a corresponding width of the wrapper spring. The addition of spring elements mainly changes the deflection. The capacity of the device can be increased by the use of two or more wrapper springs.

Another frictional device that has found extensive use on truck drawbars is based on an action which, when either pulling or pushing, simultaneously compresses a spring and forces friction segments against the inner wall of its housing (Fig. 7).

HYDRAULIC SHOCK ABSORBERS

Hydraulic shock absorbers are sometimes regarded as too complicated and sensitive for rough service, as on drawbars. The fact that many makes of hydraulic devices perform well after years on automobiles should be sufficient proof to the contrary. Generally a hydraulic shock absorber can be built lighter in weight, smaller in size, and with fewer working parts than other means of transforming energy. This advantage is offset to no small degree by necessarily close limits in the manufacturing of its component parts.

Inherent in the principle of hydraulic shock absorption is a somewhat different action under load from frictional devices and springs. Under constant pressure a hydraulic device will give a straight line as its load-deflection curve, whereas with any one of the previously described attachments no curve at all would result, if we disregard fatigue of the spring material. The ascent or descent of the curve under an increasing or decreasing load would of course be similar in both cases.

This means that a hydraulic shock absorber would have to be designed only as a protector against overload, and that shocks not exceeding the maximum capacity of the traction machine, but which nevertheless may be dangerous to the drawn machine, must be taken care of by some other means.

Of importance also is the decrease in efficiency with increasing speed. The time element is far more important with this type of device than with most others. The efficiency of a frictional device is only inconsiderably affected by such variations in velocity of action as are actually encountered.

As an example of a successful hydraulic shock absorber, one for bumpers on railroad cars, is diagrammatically shown in Fig. 8. This design resulted from experiences with recoil brakes on heavy field guns. While the device shown is not directly applicable to drawbar work on a tractor, it shows nevertheless an arrangement very similar in nature.

It shows a fluid container, a, within which is a closely fitting dish spring, b. Under load this dish spring is elastically deformed, and so, through a small fissure on its circumference, allows the fluid to pass by. After a certain pressure is attained, the device starts to work, as return valves, c, are closed by sealing surfaces, d, when the load is applied. Return to normal position in this case is accomplished by a series of layers of rubber, e. Springs could be used instead.

* * *

It must be said that a general application of shock absorbers to tractor drawbars is not feasible at present. The average tractor owner scarcely has an idea of the magnitude of forces produced by shocks under severe working conditions. To him the advantages of an elastic drawbar are not at once evident. But with increasing versatility of the tractor, we shall come to regard shock absorbers much as we do air-cleaners or radiator curtains, not as absolute necessities from an operating standpoint, but as means of getting maximum returns out of a capital investment.

[3]O. R. Wikander's calculation in "Mechanical Engineering," for February 1926.

Sugar in Portland Cement Mortars

CONSIDERABLE newspaper publicity has recently been given to the increase in tensile strength of lime mortar briquettes by the addition of sugar to the mixing water. The basis for this was a report by Gerald J. Cox and John Metschl, of the Sugar Fellowship, Mellon Institute of Industrial Research, presented at the April (1932) American Chemical Society convention in New Orleans.

The results of tension tests on lime mortar briquettes at the age of six months were reported. A 60 per cent increase was obtained in the tensile strength of lime mortar by means of sugar additions up to 6 per cent, by weight, of the lime putty.

A number of different newspapers have so re-written this that it implies that the addition of sugar to all types of mortars is beneficial. Mr. Cox specifically states, "The description of our work and our recommendations apply only to lime-sand mortar. Our search of the literature has revealed about 70 reports on the effect of the addition of sugar to portland cement. The authors are unanimous in their findings that cane sugar ruins concrete made from portland cement and must not be used."

In view of its recognized harmful effect in portland cement mixtures, the addition of sugar in any quantities to the commonly used portland cement-lime mortars, 1-1-6 and 1-1-4 mixes, should not be attempted.

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Continued Meetings

DEFYING so-called depression, the Power and Machinery Division and the Structures Division of the American Society of Agricultural Engineers will hold their usual fall meetings in Chicago, as previously announced. They see work to be done and will do it to the best of their ability.

Each division will have one session devoted to its interests in that current limiting factor in material progress—applied economics. This will also inevitably color the more strictly technical engineering sessions on forage drying, harvesting, dynamometer studies, tractor traction, general-purpose tractors, dairy housing, building materials, and farm building plan services.

With trade still faltering, employment low, winter and Congress coming on; with assorted sound, half-sound, and fanatical economic and social schemes being urged, heard, and in some cases tried; with engineering on trial before the public; with every employed agricultural engineer striving to justify his continued employment, it is urgent that agricultural engineers, among others, take every opportunity to clarify their views and those of the public on the economic and social significance of their work. Enlightened self-interest, professional spirit, and civic responsibility justify whatever sacrifices attendance may require. They will be great meetings for work, for individual and professional progress. See you there!

Agricultural Engineering's Future

REACTIONS toward inefficient subsistence farming have been an important phase of relief for the unemployed. This may lead some young agricultural engineers and other persons to question the future of the agricultural engineering profession. For such we present a viewpoint which is reassuring, and we believe sound.

Farms and farmers produce the raw materials for food and clothing—the basic necessities of human existence. Whatever heights of welfare and civilization a people are to reach, above a mere existence, can therefore only be reached by efficient farming and the workers it releases to produce other goods and services, comforts and conveniences. The application of engineering to agriculture is one of its chief means of achieving high efficiency. Agricultural engineering, therefore, seems as firmly entrenched as any element in our whole civilization, with the exception of farming.

To bolster any weakening of faith in the continued advance of civilization itself, one may review economic and social history, noting the difficulties previously overcome in the advance of civilization to date. It is true that we are in a unique situation today with greater physical mastery over the resources and conditions of nature than we know how to use for our individual and collective welfare. Undoubtedly new principles of application, new technique of control of this physical capacity must be put in effect. New philosophies of material welfare in relation to civilization, of the direction of human efforts, are implied.

We reiterate our previously expressed confidence that the minds which have developed the means to human efficiency, to dominance of material things will make that dominance a means to progress. Agricultural engineers will assist in harnessing that physical capacity; will share in the resulting progress.

Pennywise Economy

ASTRINGENT financial situation popularizes government economy, both real and pennywise. All manner of scientific and technical specialties, including agricultural engineers, in federal and state employ, are particularly apt to be victims of the pennywise variety of economy.

Some politicians cite, for their own purposes, instances of scientific investigations and publications which have no readily-apparent positive value, and use them as leverages to lower appropriations for the activities concerned. An emotionally wrought public, no better qualified to judge the real merits of the activities in question, seeing itself sinking in a sea of taxes, will grasp at such straws.

Scientific and technical specialization has separated technical workers from the public and from each other to a point of seriously decreasing mutual understanding and of encouraging the formation of narrow viewpoints. The values of technical activities are often indirect; hidden parts of broader works; difficult of appraisal by men in other fields; difficult of explanation to the voting public; but none the less worth their cost. They have been taken largely on faith, and now the faith of the public has been sorely tried by individuals and circumstances.

The resulting situation is dangerous. A well-meaning but emotional and non-technical public, accustomed to accepting the benefits of technical progress without asking how or whence they came, cannot safely take unto itself in one step, judgment of its dependence upon technical activities. The long-willing subjects of a technical patriarchy cannot achieve technical democracy by revolutionary means.

It is a responsibility of every technical profession at this time to improve its public relations, to induce the public not to stand in the way of technical progress in its own interest.

This can be accomplished in part by concentrating on activities which are timely and of readily apparent value; by careful publicizing to reveal the indirect or obscure values of other activities; and by careful justification of public faith in the planning and pursuit of all public technical activities. To those who will talk only of taxes, some pertinent questions may be posed. What proportion of tax monies is used to pay for past mistakes, and what proportion is invested in technical activities to minimize similar wastes in the future? Granting that there are some excess costs of government, are they in its technical activities? If so, the professions concerned should correct the abuse. If not, why rob Peter to pay Paul? And granting that circulation is not ordinarily an end in itself, that excess costs of government represent waste circulation of money between the government and its people, is reduction of such circulation really a prime problem in a period troubled by financial stagnation? We can all amplify these with other points to help prevent the costly practice of pennywise economy.

Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W. Trullinger, specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture. Requests for copies of publications abstracted should be addressed direct to the publisher.

Efficiencies in Irrigation, O W Israelsen (Utah Academy of Science [Salt Lake City] Proceedings, 8 [1930-1931], pp 40-43).—In a contribution from the Utah Experiment Station, an analysis is given of the measurement of efficiencies in irrigation with particular reference to the efficiency of water application, conveyance, and delivery, consumptive use efficiency, and irrigation efficiency. It appears that irrigation efficiency is influenced by the efficiency of application, conveyance and delivery, and consumptive use.

Relationship Between Volatility and Consumption of Lubricating Oils in Internal-Combustion Engines, G Wade and A L Foster (U S Department of Commerce, Bureau of Mines, Technical Paper 500 [1931], pp II + 52, figs 7).—Studies conducted in a modified tractor engine with oils from four major petroleum-producing regions and with specially prepared or blended oils are reported, the purposes being to determine the physical and chemical characteristics of the oils by the customary tests, to test each oil under definite and uniform running conditions, and, at the end of each run, to determine the amount of oil consumed and the degree of change in its physical and chemical characteristics.

All of the lubricants studied appeared to give approximately equivalent efficiencies in lubricating the engine mechanism. One of the blended oils, representing a high-sulfur lubricating distillate with a relatively wide boiling range, showed the greatest susceptibility to decomposition in use. The increase in viscosity seemed to have some relation to consumption in the engine, but so far as was determined the ratio was inexact. The increase in viscosity was found to be greater as the volatility increased this being especially noticeable in oils blended of two or more components differing widely in volatility.

No exact ratio appeared to exist between carbon residue and consumption, but in general carbon residue increased as the consumption increased. It was found that the ratio of piston carbon to consumption was more nearly exact. It also was found that the consumption ratings of the different oils were not the same under different operating conditions or for different periods of operation. In the shorter runs a blend of a light and a medium-grade oil, both made from Pennsylvania crude, was consumed at a relatively greater rate than in the longer runs.

While changes in volatility during use did not show a wide differentiation in the four commercial oils, the effect of light ends was shown in oils which were blended with varying amounts of light distillate.

The tentative conclusion is drawn that the exact and accurate evaluation of the comparative value of an oil in service is still a problem requiring exhaustive experimental and testing work, both in the laboratory and in actual use.

Foundations for Farm and Village Dwellings, G M Warren, T A H Miller, and W Ashby (U S Department of Agriculture, Bureau of Agricultural Engineering, 1931, pp 8, pl 1).—This is a contribution from the U S D A Bureau of Agricultural Engineering and represents a report submitted to the President's Conference on Home Building and Home Ownership by the committee on farm and village housing. It presents a brief description of accepted practices in the construction of small house foundations.

Representative Plans for Farm Houses, W A Foster et al (U S Department of Agriculture, Bureau of Agricultural Engineering 1931, pp 8, pls 26).—This is an extract from a report submitted to the President's Conference on Home Building and Home Ownership by the committee on farm and village housing, and presents a group of farmhouse plans which are representative of the best now available from the agricultural experiment stations, the U S D A Bureau of Agricultural Engineering, and leading agricultural journals.

Farm Gas Engines and Tractors, F R Jones (New York and London McGraw-Hill Book Co, 1932, pp X + 485, figs 503).—This book presents material which is based on the results of the author's experience in teaching the subject of farm power over a period of 15 years at the Agricultural and Mechanical College of Texas.

The book is divided into two distinct parts. Part 1 deals with the fundamental principles involved in the construction and operation of the simple internal-combustion engine with particular reference to the small stationary farm-type engine. An introductory chapter discusses the relation of farm power to agricultural production and enumerates the primary sources of power with their adaptations and disadvantages. Following a brief discussion of early gas engine development, such subjects as construction and operating principles, carburetion, ignition, and lubrication are taken up in complete detail with respect to both past and recent developments.

The second part covers the detailed construction and operation of the various types of farm tractors, and a special chapter takes up the fundamental requirements of the all-purpose or cultivating-type tractor, describing briefly the different makes now available together with their outstanding features. A final chapter deals with the tractor from the standpoint of selection and efficient utilization under different conditions.

In order to make the text better suited for use by research workers a number of references are given at the end of the more important chapters.

Characteristics of Alloyed Cast-Iron, F W Shipley (S A E [Society of Automotive Engineering] Journal [New York], 30 [1932], No 3, pp 120-128, figs 23).—Results of studies of alloyed cast iron are reported with particular reference to its use on cylinders and valve seats in tractor engines.

The results indicate that chromium in cast iron increases the hardness and strength by combining the carbon and producing a more stable double carbide of iron which crystallizes out with the pearlite. Nickel tends to dissolve this free-cementite-forming pearlite. A combination of the two alloys in the ratio of approximately 3 parts of nickel to 1 of chromium will produce an iron for engine cylinders which is superior to plain iron with respect to hardness, strength, and microscopic structure. The percentage increase of these properties varies almost as the percentage of alloys used.

Increased Brinell hardness is not desirable if accompanied by excessive free cementite, but it is an indication of increased quality when produced by a pearlitic or pearlitic-sorbitic structure. Nickel-chromium-alloyed irons are much superior with respect to heat-resistant properties than are ordinary irons. Alloying irons with chromium produces a superior chill and affords a practical method for production of special castings of this type.

A Draft Dynamometer for Teams [trans title] von OW (Fortschritte Landwirtschaft, 7 [1932], No 1, pp 15, 16, figs 3).—This dynamometer is briefly described and diagrammatically illustrated. The results of draft tests of a mowing machine are presented graphically.

Strength-Moisture Relations for Wood, T R C Wilson (U S Department of Agriculture, Technical Bulletin 282 [1932], pp 88, figs 44).—The purpose of this bulletin is to discuss the relations between the moisture content and the strength properties of small, clear specimens of wood, to outline the development of formulas that may be used in adjusting strength values for differences in moisture content, and to make clear the applicability and limitations of these formulas. Other phases of moisture-strength relations are also discussed.

Data are reported resulting from tests of the effect of moisture on the strength properties of wood as made by the Forest Service over a period of 25 years. From them a type formula is derived to express the relation between uniformly distributed moisture content and various strength properties.

[Agricultural Engineering Investigations at the Louisiana Stations], H T Barr, A H Meyer and W Whipple (Louisiana Stations [Baton Rouge] [Biennial] Report [1930-31], pp 68-73).—The progress results of studies are reported on deficiencies of agricultural implements as applied to sugar-cane culture, producing corn and soybeans with mechanical power, improved method for handling hay, subsoiling of cotton land, draft of cane wagons, artificial curing of hay, and cane milling and freezing.

[Agricultural Engineering Investigations at the Massachusetts Station], C I Gunness (Massachusetts Station [Amherst] Bulletin 280 [1932], p 195).—The progress results of experiments with apple storages, fertilizer distributors, and low-lift pumps are briefly reported.

Surface Water Supply of the United States, 1930, Parts 4, 8, 9, 12 A (U S Geological Survey, Water-Supply Papers 699 [1932], pp V + 125, fig 1; 703 [1932], pp V + 131, fig 1; 704 [1932], pp V + 117, fig 1; 707 [1932], pp VII + 196, fig 1).—Of the papers which here present the results of measurements of flow made on streams during the year ended September 30, 1930, No 699 prepared in cooperation with the States of Wisconsin, Illinois, Ohio, New York, and Vermont, covers the St. Lawrence River Basin; No 703, prepared in cooperation with the State of Texas, covers the western Gulf of Mexico basins; No 704, prepared in cooperation with the States of Wyoming, Utah, and Arizona, covers the Colorado River Basin; and No 707, pre-

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A.S.A.E. and Related Activities

PROGRAM

A.S.A.E. POWER AND MACHINERY DIVISION MEETING

The Stevens, Chicago, Illinois
November 28 and 29, 1932

First Day—Monday, November 28

Forenoon Session—9:30 to 12:00

Presiding—W. L. Zink, chairman, Power and Machinery Division

1. SYMPOSIUM: "Artificial Drying of Forage Crops"
   (a) "Power, Labor, and Fuel Requirements"—H. T. Barr, agricultural engineer, Louisiana State University.
   (b) "Nutrient Value of Artificially Dried Forage"—L. M. Kishlar, Ralston Purina Company
   (c) "Recent Developments in Drying Equipment"—A. W. Clyde, agricultural engineer, Pennsylvania State College
2. PAPER: "The Crusher-Mower in Hay Making"—Frank J. Zink, agricultural engineer, Kansas State College
3. PAPER: "Development of the 'Combine' Hay and Straw Baler"—L. R. Tallman, general manager Ann Arbor Machine Company

Afternoon Session—2:00 to 4:30

Presiding—W. L. Zink, chairman, Power and Machinery Division

1. PAPER: "A Combine for the Corn Belt"—I. D. Mayer agricultural engineer, Purdue University
   DISCUSSION (a) "Barge Method of Combine Harvesting"—J. K. MacKenzie, agricultural engineer, Caterpillar Tractor Company; (b) "Combining Soybeans in the South"—R. B. Gray, chief, division of mechanical equipment, Bureau of Agricultural Engineering, U. S. Department of Agriculture
2. PAPER: "Observations from Corn Picker Studies"—C. K. Shedd, agricultural Engineer, Bureau of Agricultural Engineering, U.S. Department of Agriculture
3. PAPER: "Threshing Machine Tests and Testing Equipment"—G. W. McCuen, agricultural engineer, Ohio State University

Evening Session—7:30 to 10:00

Committee and Group Round Table Conferences (Arranged on request)

Second Day—Tuesday, November 29

Forenoon Session—9.30 to 12:00

Presiding—R. B. Gray, vice-chairman, Power and Machinery Division

1. PAPER: "Some Economic Aspects of Farm Mechanization"—Arnold P. Yerkes, International Harvester Company
   DISCUSSION: (a) Leonard J. Fletcher, agricultural engineer, Caterpillar Tractor Company; (b) Harper Sibley, manager, Sibley Farms; (c) D. Howard Doane and C. H. Everett, Doane Agricultural Service

Afternoon Session—2:00 to 4:30

Presiding—W. L. Zink, chairman, Power and Machinery Division

1. PAPER: "Efficiency Tests of Tractor Wheels and Tracks"—E. V. Collins, agricultural engineer, Iowa Agricultural Experiment Station
2. PAPER: "Pneumatic Tires for Agricultural Tractors"—J. W. Shields, field engineer, Firestone Tire and Rubber Company
   DISCUSSION: (a) G. W. McCuen, agricultural engineer, Ohio State University; (b) E. F. Brunner, tire design division, Goodyear Tire & Rubber Company
3. PAPER: "Valve Problems and Recent Developments in Valves"—A. T. Colwell, chief engineer, Thompson Products, Inc.

Wednesday, November 30

Round Table Session—9:30 a.m.

SUBJECT: "The General-Purpose Agricultural Tractor"

(To be devoted largely to informal discussions of the engineering problems involved in the development and application of the general-purpose tractor.)

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PROGRAM

A.S.A.E. STRUCTURES DIVISION MEETING

The Stevens, Chicago, Illinois
November 28 and 29, 1932

First Day—Monday, November 28

Forenoon Session—9:30 to 12:00

Presiding—Henry Giese, chairman, Structures Division

1. PAPER: "The Relation of Stable Air Conditions to Milk Production"—M. A. R. Kelley, agricultural engineer, Bureau of Agricultural Engineering, U.S. Department of Agriculture
2. PAPER: "Problems in the Design and Adoption of Milk Houses"—J. B. Kelley, agricultural engineer, University of Kentucky

Afternoon Session—2:00 to 4:30

Presiding—Henry Giese, chairman, Structures Division

1. PAPER: "Industrial Decentralization and Rural Housing Problems"—Harry R. O'Brien, agricultural writer
2. PAPER: "Cooperation Between Lumber Dealers and State Colleges in a Better-Buildings Program"—Ormie C. Lance, secretary, Northwestern Lumbermen's Association
3. REPORT: Committee on Economics of Farm Buildings, J. C. Wooley, chairman

Evening Session—7:30 to 10:00

Committee and Group Round Tables (by arrangement)

Second Day—Tuesday, November 29

Forenoon Session—9.30 to 12:00

Presiding—C. F. Miller, vice chairman, Structures Division

1. PAPER: "Metallic Zinc Paints"—Geo. C. Bartells, chemical engineer, American Zinc Institute
2. PAPER: "Recent Developments in Roofing Nail Design"—A. J. Deniston, Jr., The Denniston Company
3. SYMPOSIUM: "Preservative Treatments for Masonry Silo Walls"—F. C. Fenton, agricultural engineer, Kansas State College; C. F. Steigerwalt, agricultural engineer, Portland Cement Association; S. A. Witzel, agricultural engineer, University of Wisconsin

Afternoon Session—2:00 to 4:30

Presiding—C. F. Miller, vice chairman, Structures Division

1. REPORT: Committee on Coordination of Building Plans, W. G. Ward, chairman
2. Business Session

Southern Section Meeting in February

THE Southern Section of the American Society of Agricultural Engineers will meet in New Orleans February 1, 2 and 3 in conjunction with the annual meeting of the Association of Southern Agricultural Workers, according to an announcement by W. A. Clegg, Chairman of the Section.

Inasmuch as the central theme of the general program of the Association at its next meeting is "Economics as Applied to Rural Life," the program of the Southern Section will be planned to fit in to this central theme. in connection with which considerable attention will be given to the general subject of the economics of farm production, with which agricultural engineers are particularly concerned.

The program will consist of three half-day sessions, which will be held on the afternoons of February 1, 2, and 3. The forenoon periods of these days are devoted to the general program sessions of the Association of Southern Agricultural Workers, the afternoon periods being given over to the various subject-matter groups in agriculture, which, in addition to agricultural engineering, include animal husbandry, dairy husbandry, poultry husbandry, agronomy, soils and fertilizers, crops and plant breeding, agricultural economics, economic entomology, forestry, horticulture, and home economics.

It is anticipated that the agricultural engineering group will be represented on the general A.S.A.W. program by an illustrated lecture, entitled "The Farm Dwelling," to be delivered by one of the prominent agricultural engineers of the South who has given this subject exhaustive study especially from the point of view of the requirements of farm families in the southern states.

According to the tentative plans for the agricultural engineering program the first afternoon session (February 1) will be devoted, for the most part, to the subject of agricultural engineering extension work. The more important branches of extension work will be featured, including farm machinery (covering especially one and two-row crop equipment), farm drainage, and farm buildings; the last-named will be confined for the most part to barns and other buildings other than dwellings. Those contributing to this program are all agricultural extension engineers connected with land-grant institutions of the South, and they will take up their respective subjects from the economic point of view.

It is planned to feature also at this session a paper on the relation of an

agricultural engineering program to vocational agricultural education, to be presented by a regional supervisor of vocational agricultural education. The purpose of this feature is to foster understanding and cooperation between the vocational and engineering groups of workers.

The second afternoon session of the agricultural-engineering group will feature a soil erosion control program, this subject being of great interest and importance to southern agriculture, in which part of the country soil erosion control has had the most thorough scientific and economic study, and where it has been most extensively applied. The principal paper on this program, it is planned, will deal with the methods employed and the results of the work at the several federal soil erosion control field experiment stations located in different parts of the country. There will also be presented a report on the erosion control research project being conducted by the agricultural engineers at the Alabama Polytechnic Institute. One of the agricultural managers of the South has made an extensive study of the relation of soil structure to erosion control, the results of which he will present in a paper at this session.

The third and last session of this meeting of the Southern Section (on February 3) will — in addition to a business meeting during the latter part of the session—devote attention to a number of general subjects, which will include (1) a paper on electricity in farm homes from the economic standpoint, (2) a report on a cotton ginning research project, (3) a technical paper on methods of field research in agricultural engineering by one of the engineers of the Bureau of Agricultural Engineering of the U. S. Department of Agriculture.

The Southern Section looks forward to its meeting at New Orleans being honored by the presence of the president of the American Society of Agricultural Engineers, Charles E. Seitz, professor and head of the department of agricultural engineering at the Virginia Polytechnic Institute, who will be asked to address the meeting on a subject of particular interest to agricultural engineers of the South.

Haswell Heads North Atlantic Section

JOHN ROBERT HASWELL, extension agricultural engineer, Pennsylvania State College, was elected chairman of the North Atlantic Section of the American Society of Agricultural Engineers at its meeting at Albany, N. Y., October 27, 28, and 29. The newly elected vice-chairman of the Section is Geo. E. Simmons, professor of agricultural engineering (head of the department of agronomy), University of Maine. G. A. Rietz, agricultural engineer, General Electric Company, was re-elected secretary-treasurer of this Section.

The meeting was unusually well attended; the attendance included representatives from every state included in the territory of the section.

Pacific Coast Section to Meet in January

AT THE last meeting of the executive committee of the Pacific Coast Section of the American Society of Agricultural Engineers it was decided, largely on account of the general economic situation, not to hold the usual fall meeting of the Section, but to devote special attention to preparations for the Section's meeting in January, which will be held at either San Jose or Santa Clara, the tentative date decided upon being January 20. The executive committee of the Section will arrange the program which will be presented at that meeting and which will be announced in the December number of AGRICULTURAL ENGINEERING.

Inasmuch as the Council of the American Society of Agricultural Engineers at its last meeting in June voted to hold the 28th annual meeting of the Society at Asilomar, California, in June 1934, the executive committee of the Pacific Coast Section has already appointed special committees to have charge of various phases of the arrangements for the 1934 annual meeting. Preparations for this meeting are already getting under way.

Personals of ASAE Members

Roy Bainer, assistant professor of agricultural engineering, University of California, and assistant agricultural engineer in the California Experiment Station, is author of Bulletin 541, entitled "Harvesting and Drying Rough Rice in California," just issued by that institution.

Herbert Beresford, agricultural engineer, Idaho Agricultural Experiment Station, and secretary and project director, Idaho Committee on the Relations of Electricity to Agriculture, is author of Circular No. 68, entitled "Electric Soil and Hot Bed Heating," recently published by the University of Idaho, Moscow.

M. H. Byrom, Dan Scoates and **H. P. Smith**, agricultural engineers, Texas Agricultural Experiment Station, are three of the authors of Bulletin No. 452, entitled "The Mechanical Harvesting of Cotton," just published by that station.

Deane G. Carter, professor of agricultural engineering, University of Arkansas, is author of Bulletin 276, entitled "Studies in the Design of Kitchens and Kitchen Equipment," recently issued by that institution.

Leonard J. Fletcher, past-president of the Society, and agricultural engineer, Caterpillar Tractor Company, in his capacity as the official representative of the Society in matters pertaining to land utilization, attended the meeting of the National Advisory and Legislative Committee on Land Use in Washington, November 12 and 13.

O. E. Hughes, formerly a member of the agricultural engineering staff, University of Missouri, has recently been appointed special county agent of Chatham County, Georgia. His new address is Room 240, Postoffice Building, Savannah.

F. N. G. Kranick, a past-president of the A.S.A.E., and assistant to the president, J. I. Case Company, addressed a meeting of the Milwaukee Section of the Society of Automotive Engineers on November 2 on the subject, "Some Aspects of Tractor Economics."

Mark R. Kulp, assistant professor of agricultural engineering and irrigationist of the agricultural experiment station, University of Idaho, is author of Extension Circular No. 43, entitled "Farm Water Measurement," recently issued by the agricultural engineering division of that institution.

C. A. Logan, agricultural engineer, Kansas State College, is author of Bulletin No. 30, entitled "Farm Lighting Systems," just published by the engineering experiment station of Kansas State College.

New ASAE Members

George N. Harper, agricultural engineer, Virginia Electric & Power Company, Norfolk, Va.

M. A. Jones, graduate laboratory assistant, agricultural engineering department, Alabama Polytechnic Institute, Auburn, Ala. (Mail) Box 781.

J. W. Shields, field engineer, Firestone Tire & Rubber Co., Akron, Ohio. (Mail) 213 Crescent Drive.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the October issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Andres P. Aglibut, instructor in the departments of agricultural engineering and agricultural education, College of Agriculture, University of the Philippines. (Mail) Agricultural College, Laguna, P. I.

W. J. Gillespie, Jr., R. F. D. No. 1, Tazewell, Va.

Cadwallader W. Kelsey, president, Rotottiller, Inc., Long Island City, N. Y.